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PhD Thesis No. 151

Inquiries into Economic Growth, Natural Resources, and Labor
Allocation

by

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May 2007
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INQUIRIES INTO ECONOMIC GROWTH,
NATURAL RESOURCES, AND LABOR
ALLOCATION

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Ph.D. Thesis

Department of Economics
University of Copenhagen

February 2007

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Preface and Acknowledgments

This collection of essays constitutes my Ph.D. thesis, submitted to the Department of Economics at the University of Copenhagen in February 2007.

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I also wish to express my gratitude to Graciela Chichilnisky. I thank her for inviting me to the Department of Economics at the Columbia University, where I, as a visiting student, spent the year of 2004; and for the outstanding hospitality and engagement which she and the entire Columbia faculty showed me.

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I also wish to thank my colleagues at the Economic Policy Research Unit (EPRU) for inviting me to join a stimulating and collegial research environment; Vibeke Ring for assistance in my literature search; and Olga Gorbachev, Jesper Linaa, Jens Erik Nielsen, and Jacob Weisdorf, without whom my life as a Ph.D. student would have been much less enjoyable.

My family and friends have been dear oases of solicitude and support; I am deeply grateful to you all.

Copenhagen, February 2007.

Summary

This thesis consists of four chapters. Each chapter is self-contained and can be read independently. The first chapter presents a general equilibrium model of the gender wage gap. The following three chapters study issues of natural resources and economic growth. A summery review of each chapter is provided below.

Chapter 1, *An Equilibrium Analysis of the Gender Wage Gap*, presents a static general equilibrium model. It combines issues of household division of labor and issues of labor compensation in order to study how their determination is linked. In this model, spouses, who are generically identical except for gender, divide their labor between a formal sector and a home sector. Due to indivisibility effects, productivity of labor in the formal sector is negatively related to labor used in the home; at the same time labor inputs are complementary in home production.

We show that initial beliefs about a gender wage gap are self-fulfilling, and a central result is multiplicity of equilibria. Spouses allocate their labor equally, if they expect to earn the same wage rates. This labor allocation reinforces equal wage rates. In contrast, spouses allocate their labor differently, if they expect to earn different wage rates. The latter situation manifests itself in a gender wage gap. Based on this result, we argue that the apparent inertia in the reduction of the gender wage gap can be explained by inertia in the effacement of traditional gender roles, and that the latter inertia is not puzzling in that such gender roles are self-fulfilling and therefore correspond to economic outcomes.

By use of numerical examples, we show that welfare is highest when spouses allocate labor equally. As a general discussion, we relate this finding to how policies can be improved. Specifically, we argue that effective policies are policies that change norms of society.

Chapter 2, *Empirics of Economic Growth and Natural Resources*, surveys 17 studies on the so-called resource curse, which describes a negative relationship between natural resources and, typically, growth performance.

During recent decades, the idea of a resource curse has become increasingly

widespread among economists. Yet endogenous growth theory generally suggests that greater endowments provide better opportunities for economic growth. Theory alone, however, cannot tell us a priori if, or when, natural resources are a curse. We therefore examine empirical work to answer the following questions: How is natural resource abundance related to economic growth? Especially, does natural resource type matter, and does it matter how natural resources are measured? What are the pathways through which natural resources and growth potentially are correlated?

Based on our survey, we conclude that the type of the natural resource matters. There seems to be more evidence of a negative correlation between point resources (resources with a high value concentration) and growth, than between diffuse resources (resources with a scattered value concentration) and growth. It also matters how natural resources are measured. Measured in relative terms, such as relative to the overall size of the economy, natural resources seem consistently negatively correlated with growth performance. In contrast, there is little empirical evidence to support that absolute levels of natural resources have a negative impact on growth.

Pathways that link natural resources and economic growth are numerous. Point resources appear to cast their curse through weakened human capital accumulation, damaged institutional quality, increased debt, and worsened terms of trade, but, at the same there is also evidence that point resources bless growth through better institutional quality. Also diffuse resources are found to both harm and benefit institutional quality. Studies which use an interaction term between natural resources and institutional quality generally find that natural resources are a blessing for growth if institutional quality is good.

As a supplement to the survey, we provide additional data. By means of a simple cross sectional regression we examine the relationship between the size of natural resource industries relative to GDP and economic growth. We find that the relative size of both the mining and the fishing industry has no impact on economic growth averaged over 1991-2003, whereas the relative size of the combined agricultural and forestry industry is significantly negatively correlated with growth. These results are in conformity with a few studies included in the survey, but seem to diverge from

the “general pattern.” A general pattern in how various types of natural resources impacts growth, however, is not easily established.

The two subsequent chapters take a theoretical approach. Their overall purpose is to contribute to the understanding of the channels through which natural resources and growth can be related, and of why some countries seem to suffer from the resource curse, while others seem to escape it. Chapter 3, *Spending Natural Resource Revenues in an Altruistic Growth Model*, examines how revenues from a natural resource interact with both growth and welfare in an overlapping generations model with altruism. In this model, revenues from the natural resources are allocated between public productive services and direct transfers to members of society by spending policies. We analyze how spending policies influence the dynamics of the model, and how the dynamics are influenced by abundance of the natural resources. We consider a range of spending policies: exogenous policies, growth maximizing policies, policies determined by the young generation, and policies determined by the old generation.

We find that an increase in the resource revenues may harm growth for two reasons: either because spending policies favor the old generation, and consumption smoothing leads the young to decrease their saving, or because a new growth path with a lower growth rate maximizes welfare. Hence, we also show that growth and welfare can be oppositely affected by changes in resource abundance.

Due to externality issues, we provide also the socially optimal policy. Along an optimal growth path both growth and welfare benefit from higher resource revenues. Overall, the analysis suggests that variation in the strength of altruism and in spending policies may explain why natural resources seems to affect economic performance across nations differently.

The fourth and last chapter, *Labor Mobility, Household Production, and the Dutch Disease*, introduces issues of gender-based labor market patterns into a Dutch disease model with learning by doing. The idea is to study how labor mobility, and labor immobility, impact economic adjustment to altered resource abundance.

We model an economy of three sectors: a traded sector, a non-traded sector, and

a household sector. Only women work in the households. Since it seems that there is a large variation across nations in how labor markets are structured, especially, with respect to gender-segmentation, we analyze both economies with mobile labor and economies with gender specific sectors. In the latter type of labor market, in addition to working in the household, women work in either the traded or the non-traded sector, and men allocate all their labor to the sector not occupied by women.

The effect of enhanced natural resource abundance on factor allocation, the real exchange rate, wage rates, production, and growth are worked out for each case. By considering the different types of labor markets, our model predicts manifold economic outcomes. In addition, the analysis demonstrates that considering labor market types jointly with issues of natural resource abundance explains variation of societal patterns within similar types of labor markets. For instance, our model predicts that if women, besides in the household, work in traded sectors, women in natural *resource rich* countries will allocate less labor to the labor market than women in otherwise identical natural *resource poor* countries. On the other hand, if women work in non-traded sectors, besides in the household, their labor allocation is unaffected by altered natural resource abundance.

CHAPTER 1

An Equilibrium Analysis of the Gender Wage Gap

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February 2007

Abstract

This paper studies the gender wage gap within a general equilibrium model in which spouses divide their labor between a formal sector and a home sector. Due to indivisibility effects, productivity of labor in the formal sector is negatively related to labor used in the home; at the same time labor inputs are complementary in home production. We show that beliefs about the gender wage gap are self-fulfilling, and a central result is multiplicity of equilibria. Spouses allocate their labor equally, if they expect to earn the same wage rates, which ex post reinforces equal wage rates; whereas they allocate their labor differently, if they expect to earn different wage rates. The latter situation manifests itself in a gender wage gap. By use of numerical examples, we show that welfare is highest when spouses allocate labor equally. We relate this finding to policy recommendations.

Key Words: Gender Wage Gap, Household Models, Household Production, Labor Markets.

JEL Classification Codes: D13, J16, J22, J30

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1 Introduction

This paper studies issues of intra-household division of labor, labor productivity, and labor compensation within a general equilibrium model. The purpose is to contribute to our understanding of the current seemingly persistent gender wage gap situation in modern society as well as of its welfare properties.

One strand of the gender wage gap literature explains the gender wage gap by an inherent source of difference between men and women, which causes women to earn lower wages. For example, Elul et al. (2002) suggest that gender-differences in wages can be attributed to demographic reasons. Men marry younger women, and men therefore, before getting married, have the opportunity to settle where they receive maximal compensation. Women, on the other hand, marry at younger age and are accordingly more likely to settle where their compensation is not at maximum. Siow (1998) attribute differences in earnings to a biological factor: differences in fecundity. Women are only able to have children in a limited period of their lives, whereas men are not subject to this restriction. Men therefore need extra income to have children when old, and thus have an incentive to work more than women. This leads to higher male human capital accumulation and, consequently, higher male wage rates relative to female wage rates.

This paper, in contrast, builds on the strand of literature which includes Becker's (1985) seminal work on sexual division of labor, Chichilnisky (2005), Chichilnisky and Eisenberger (2005), as well as Albanesi and Olivetti (2006). This literature considers an economy in which men and women, who constitute couples (households), are ex ante generically identical except for gender.

In Becker (1985), as a result of specialization gains in at least one sector, spouses gain from a division of labor between employment and household work: one specializes in employment and the other specializes at home. Such a division raises the productivity of both persons in both sectors. Furthermore, a gender wage gap is Pareto efficient. Chichilnisky (2005) and Chichilnisky and Eisenberger (2005) also argue that there are specialization (learning by doing) effects, but, in contrast

to Becker (1985), they invoke a logistic production function, which changes from convexity to concavity through an inflection point. Chichilnisky and Eisenberger (2005) show that for the concave part of the production function, to which highly skilled societies belong, equal wage is efficient, whereas for the convex part of the production function, to which unskilled societies belong, efficiency requires specialization. In order to explain the current unequal labor allocation between men and women in highly skilled societies, in which, within the logistic model, efficiency requires equal wages, Chichilnisky (2005) argues that missing contracts between the family and the workplace, and absence of private property rights to labor input within households, lead to an outcome with an unequal division of labor between husband and wife. Firms and families play a Prisoner's dilemma game, and the outcome is a Pareto inefficient gender wage gap outcome. Chichilnisky (ibid., 15) argues that "there is a cooperative solution that is better for all, involving equity at home and in the workplace, but it seems riskier."

Another closely related but independent paper is Albanesi and Olivetti (2006). Albanesi and Olivetti focus on labor market attachment. Household members choose both effort and home hours, and firms face incentive problems. The paper examines two situations: the situation with an initial difference in men's and women's productivities, and the situation without. In the latter, which resembles the assumptions in our model, the authors find two types of equilibria: One equilibrium involves equal wages and the other equilibrium involves unequal wages.

To complement this literature, this paper modifies the household sector in an economy otherwise comparable to Becker's (1985) model by changing the home production function. We introduce *complementarity* of labor in home production (using a Cobb-Douglas specification) and maintain an assumption of specialization gains, which we refer to as *indivisibility* effects, of labor in the workplace. Indivisibility effects of labor in the workplace imply that one employee working $2T$ hours a day produces more than two employees each working T hours a day.¹ A conse-

¹It can be argued that the gap in hourly wages between part-time and full-time jobs to some extent reflects differences in effectiveness between short and long hours. Such a gap has been

quence of this effect is that the less labor a worker puts into home production, the more productive the worker is at the workplace.

Households are described by a standard unitary household model and labor is allocated as to achieve intra-household efficiency. If spouses expect to earn different wage rates, they allocate their labor differently. On the other hand, if spouses expect to earn the same wage rate, they allocate their labor identically. Firms are non-discriminating,² competitive, and hire workers taking as given the supply of labor (in terms of hours)³ of each worker. They hire workers until the marginal productivity of a worker equals her marginal costs (her salary). Firms are therefore willing to hire both low and high productivity workers, if the workers' wage rates vary accordingly. In equilibrium, a worker, who works long hours, earns a high wage, and a worker who works short hours earns a low wage.

As in Chichilnisky (2005) and in Albanesi and Olivetti (2006), we find that there exist both an equilibrium in which spouses differ in their labor allocation, and earn different wages, and an equilibrium in which all workers have identical labor allocations, and earn the same wage. A gender wage gap occurs when there are gender-differences in labor allocation. In turn, gender-differences in labor allocation occur if the beliefs about wages are stereotype.⁴ If indeed beliefs are stereotype, the labor market dictates a wage rate for women and a wage rate for men.⁵

reported repeatedly, e.g., by the U.S. Department of Labor (2005). In 2004, a full-time worker in the US earned about \$19 per hour, whereas part-time workers earned only \$10. A portion of the difference, however, may be accounted for when occupational differences. Hirsch (2000) finds that the part-time wage gap diminishes considerably by controlling for age, gender, skill level, and other variables. Also Bonke et al. (2005) discuss how increasing hours in household production are correlated with wages. They find that household work has a negative effect on female wages. The same is not completely true for men: low-end male wages are positively correlated with household work.

²Meyersson Milgrom et al. (2001) find that, within Sweden, men and women doing the same work for the employer are paid the same salary. In academic labor markets, however, evidence of discrimination has consistently appeared (Blackaby et al. 2005).

³This assumption at first may seem to contradict the conventional assumption that labor demand is decreasing in wages. This would be true if we did not distinguish between the number of workers and number of hours worked. Indeed, we postulate that workers and hours are not perfectly substitutable (see, e.g., Cahuc and Zylberberg (2004) for a discussion).

⁴By stereotype, we mean traditional patterns of sex roles.

⁵We stress that this mechanism is conceptually different from discrimination since, in our model, the wage rate for men and women coincides when initial beliefs are unisex.

We find by use of numerical examples that welfare in society is highest when spouses' labor allocation and wage rates are the same. This result supports the Pareto efficiency result of Chichilnisky (2005). In particular, we show that Becker's result does not hold when productivity of labor input of each family member in household production is dependent of the other. How, then, can the seemingly persistency of the gender wage gap in modern society be explained? We suggest that the self-fulfilling nature of traditional gender roles impedes their effacement.

There is also a large body of empirical literature which analyzes the gender wage gap. Explanations include the so-called family gap: women who marry and have children experience a higher wage gap than unmarried women with no children (Ginther 2004; Waldfogel 1998; Winder 2004), job segmentation, i.e., men and women are allocated differently to occupations that differ in the wages they pay (Meyersson Milgrom et al. 2001), and self-selection of women into sectors that have experienced a relatively lower wage growth (Rosholm and Smith 1996). Other explanations suggest that family-friendly policies may have adverse effects on female wages (Gupta et al. 2006), or that evidence of a glass ceiling effect⁶ prevents women from being paid the same as men (Meyersson Milgrom and Petersen 2006). Finally, Blackaby et al. (2005) suggest that discrimination causes women to be underpaid. Still, however, a large fraction of the gender wage gap seems to remain unaccounted for (Blau and Kahn 2006).

This paper proceeds as follows. In the next section we provide some evidence that motivates our model. Section 3 develops a model in full generality by describing the representative two-person family, the representative firm, and the equilibrium. In section 4, we solve our model and present the results. In section 5, we discuss the welfare aspects of equilibria, and in section 6, we discuss policy implications. The final section provides some concluding remarks.

⁶The glass ceiling effect refers to a situation within firms in which there is a rank or level beyond which women are rarely promoted.

2 Background

Female labor force participation has increased substantially during the last half century in advanced economies.

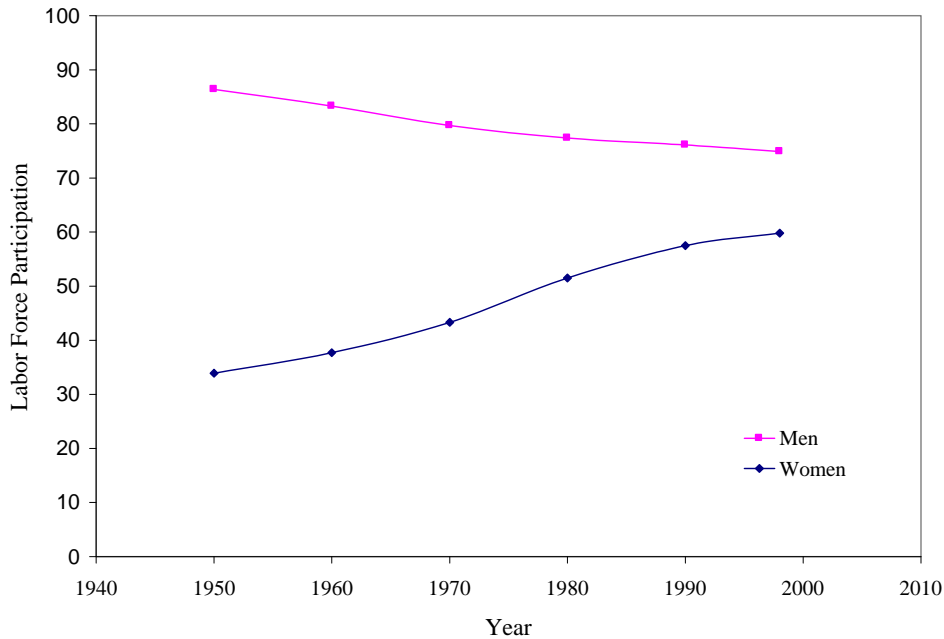


Figure 1: US labor force participation for men and women, 1950-98. (Data from Fullerton 1999, table 1.)

As an illustration, fig. 1 shows how men and women’s labor force participation rates have evolved in the US since the 1950s. The female labor force participation rates rose from 34 percent in 1950 to 60 percent in 1998. In the same period, the male labor force participation rates declined from 86 percent to 75 percent. As a result, the difference in labor force participation rates went down from 53 percent in 1950 to 15 percent in 1998 (Fullerton 1999). In addition, women’s educational achievements are rising. In the US, women have overtaken the role as the most educated sex since the mid-90s (Freeman 2004). Yet despite these advancements of women’s position in the labor force, and despite “equal work equal pay” regulations in many countries,⁷ women do not seem to be making the same salaries as men.

⁷ILO’s Equal Remuneration Convention no. C100 has, since its enactment in 1951, been ratified

After women entered the labor force, the gender wage gap⁸ has been closing. In the US, the gap converged in the 1980s after a stable period in the 1960s and 1970s (Blau and Kahn 2000). Since then the convergence has slowed. Fig. 2 shows how the gender wage gap has evolved since 1979. The slope in the first part of the period is significantly⁹ different from the slope of the second period.

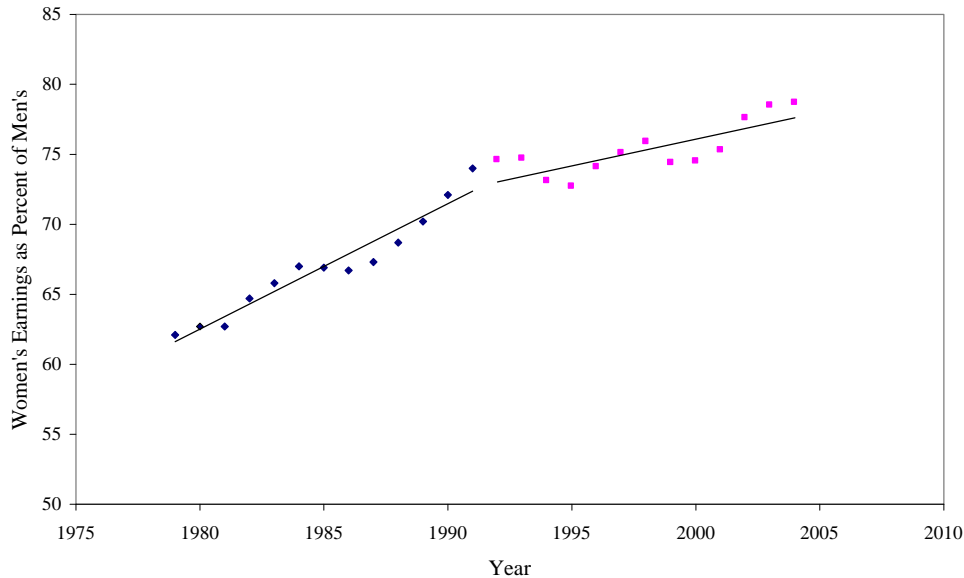


Figure 2: The US gender wage gap, 1979-2004. (Data from U.S. Department of Labor 2005, table 16.)

Indeed, Blau and Kahn (2006) find that in the US, the gender wage gap has remained almost constant since the early 1990s. Similar findings are presented for other advanced economies, such as those of Sweden (Edin and Richardson 2002) and Denmark (Gupta et al. 2006). In the OECD countries, on average, women earn 84 percent of male hourly earnings (OECD 2002). There is some evidence, however, that new cohorts of women fare better than previous ones (Blau and Kahn 2000).

by 162 countries, <http://www.ilo.org/ilolex/english/convdisp2.htm>.

⁸In general, the gender wage gap is a rough estimate that includes both differences in earnings across “male and female occupations” as well as differences in male and female earnings within the same occupation. One should therefore be careful when comparing wage gap estimates from different sources.

⁹The null hypothesis of a common slope is rejected at the 1 percent level by use of a f-test.

We also base our theory on another empirical regularity; namely, that today's division of labor between spouses within the household seems surprisingly traditional. Numerous time-use studies show that wives spend relatively more time in home production than husbands, and that husbands spend relatively more time in the workplace than wives. Table 1 shows the results from different surveys of which most are sampled in the early 1990s.¹⁰ It presents hours spent on household work and labor market work on a working weekday.

Table 1 Allocation of Daily Work Hours between the Home and the Workplace

	Market		Home		Total	
	Women	Men	Women	Men	Women	Men
Canada	8.5	9.6	2.8	1.7	11.3	11.3
Netherlands	4.1	6.7	4.0	2.0	8.1	8.7
Norway	7.2	8.7	3.4	2.1	10.6	10.8
UK	6.9	8.8	3.3	1.3	10.2	10.1
US	8.4	9.3	2.5	1.5	10.9	10.8
Italy	6.5	7.9	4.0	0.9	10.5	8.8
Austria	7.9	9.8	3.7	1.3	11.6	11.1

Source: Data from Freeman and Schettkat 2005, table 7.

The table shows that for a range of developed economies, women do relatively less market work and men do relatively less work in the home. Yet in total (with the exception of Italy), men and women roughly spend the same amount of time on the two activities. In conformity with these findings, Short (2000) reports that in 1999, still British men used less time in household production than did British women, and British men used more time on paid work than did British women. Bonke et al. (2005) find similar results in Danish data.

This pattern in labor allocation is in accordance with the fact that women occupy 68 percent of all part-time jobs. About half of those women are married, whereas the share of part-time workers, who are married men, is as low as 9 percent (U.S. Department of Labor 2005, table 4).

In summary, it seems that despite women and men roughly share same initial

¹⁰Freeman and Schettkat (2005) contains a full specification of the sampling years.

educational levels, their labor allocation patterns diverge. In particular, this divergence manifests itself as unequal labor allocation between the home and the labor market, and as gender-differences in wages. We proceed to suggest how this pattern can be rationalized.

3 The Model

The economy consists of two sectors, a formal sector and a home sector. Each sector is constituted by a number of identical firms and families. The home sector produces household services and the formal sector produces a market commodity.

The constant \bar{N} denotes the number of families. Families consist of a husband and a wife, who are identified by an index $i \in \{1, 2\}$. Family members are ex ante identical except for gender. They supply labor to the firm, l_i , and to the family, t_i , and have constant labor endowments, \bar{T} . We think of the labor endowment as the daily number of hours used for work activities (cf. table 1); thus,

$$l_i + t_i = \bar{T},^{11}$$

and henceforth, l_i and t_i are in the following expressed in number of hours as a share of total daily labor endowment. Family members do not derive utility from leisure and personal time.

3.1 Families

The representative family consumes the market commodity, x , and household services, z , which we think of as including activities such as food preparation, dish washing, household up-keeping, care for clothes, child care, shopping, do-it-yourself work, gardening, and so forth. The market commodity is purchased from the market. The household service, on the other hand, is produced and consumed entirely within the home.¹²

¹¹We shall refer to any combination $(t_i, l_i) = (t_i, \bar{T} - t_i)$ as the family member's labor (or time) allocation between the home sector and the firm sector.

¹²One could argue that household services are to a certain extent available on a formal market. Time-use studies, however, show that families produce (at least part of) the service themselves (Bonke et al. 2005; Freeman and Schekatt 2005; Short 2000).

We assume strict essentiality and complementarity in home production in the sense that one family member cannot produce without labor input from her spouse. Strict essentiality seems justifiable for household activities which concern reproduction. More generally, one can argue that without mutual affection and attention, there will be no household production by either family member. Specifically, home production is given as

$$z = (t_1 t_2)^{\frac{\beta}{2}}, \quad (1)$$

where, if $z > 0$, then $t_1 > 0$ and $t_2 > 0$. Moreover, $0 < \beta \leq 1$. We assume there are constant or decreasing returns to male and female labor input taken together. The literature shows no strong prior on this point,¹³ but the constant returns formulation is often used for its convenience in empirical analysis (Apps and Rees 1997; Aronsson et al. 2001). Note that the factor shares of female and male labor input are taken to be identical. This reflects the idea that husband and wife are equally productive if they allocate their labor equally.

Each family member has identical preferences and an equal weight in the family welfare function in conformity with a conventional unitary household model¹⁴ with household production. The family utility function, u , is for convenience taken to be linearly additive:

$$u(x, z) = ax + bz, \quad (2)$$

where $a > 0$ and $b > 0$ are parameters. For given *hourly* wage rates, w_1 and w_2 , the family maximizes its utility

$$\max_{t_1, t_2} u(x, z) \quad (3)$$

¹³Becker (1985), Chichilnisky (2005), and Chichilnisky and Eisenberger (2005) do not assume complementarity in home production. Becker (1985) furthermore assumes specialization gains, whereas Chichilnisky (2005) and Chichilnisky and Eisenberger (2005) assume a logistic production function.

¹⁴This aspect of our model could be made more general by using a collective household model (Chiappori 1988) which allows household members to have different preferences and to have different weights in the family welfare function.

subject to its budget, production, and labor constraints:

$$p_x x = w_1 l_1 + w_2 l_2, \quad (4)$$

$$z = (t_1 t_2)^{\frac{\beta}{2}}, \quad (5)$$

$$l_i + t_i = \bar{T}, \quad i \in \{1, 2\}, \quad (6)$$

$$l_i \geq 0, \quad t_i \geq 0, \quad (7)$$

by efficiently allocating labor to home production and to earning market wages. The price, p_x , of the market commodity is our *numeraire*.

The household service is not traded, and therefore it has no market price. However, a price for the household service, p_z , can be defined as a shadow price at an optimum. Using the wage rate as the shadow price of labor input to home production, we can, as intra-household efficiency in the family consumption allocation requires that the marginal rate of substitution between the two goods equals their price ratio, $\frac{\partial u / \partial x}{\partial u / \partial z} = \frac{p_x}{p_z}$, derive p_z as the ratio $\frac{b}{a}$.

In a solution where $l_i > 0$ and $t_i > 0$, an efficient allocation of labor endowments is reached when the marginal value product of labor in home production equals its opportunity cost (the hourly wage rate). Specifically, the first order conditions to the family utility maximization problem in such a solution can be expressed as

$$\frac{b}{a} \frac{\partial (t_1 t_2)^{\frac{\beta}{2}}}{\partial t_1} = w_1, \quad (8)$$

$$\frac{b}{a} \frac{\partial (t_1 t_2)^{\frac{\beta}{2}}}{\partial t_2} = w_2, \quad (9)$$

and dividing (8) by (9), we obtain an expression for the gender wage ratio (or gap):

$$\frac{w_1}{w_2} = \frac{t_2}{t_1}. \quad (10)$$

By (10), the wage ratio equals the inverse ratio of labor input into household production; if a family member earns relatively higher wage rates than her spouse, she allocates relatively less time in home production than her spouse, and vice versa.¹⁵

If family members earn the same wage rate, they allocate labor in the same manner.

¹⁵This prediction is tested by Albanesi and Olivetti (2006) on American data. They find a significant negative correlation between the husband-wife ratio of earnings and their home hours ratio.

The first order conditions, (8) and (9), are in general not satisfied in case of boundary solutions, i.e., when $l_i = 0$ or $t_i = 0$. Such situations occur if the marginal cost of the household service is different from its price for any allocation of labor.

3.2 Firms

The representative firm operates in a competitive market and produces the market commodity taking labor as input. It decides how many male and female workers, N_1 and N_2 , to employ taking the hours of labor supplied by each worker and the hourly wage rates as given.

Each worker produces an output. Let e denote effectiveness of each unit of labor input at the firm. We assume that effectiveness is unrelated to gender type, but only a function of labor allocation. In particular, we assume that due to indivisibility of labor in the workplace, effectiveness is (linearly) increasing in hours per day in employment:

$$e = e(l_i) = l_i, \tag{11}$$

so $\frac{\partial e(l_i)}{\partial l_i} > 0$.

Indivisibility effects of labor in the workplace imply that one employee working $2T$ hours produces more than two employees each working T hours. Arguments in favor of this relationship include sunk costs such as start-up costs. Moreover, if more workers are assigned on the same project, they may have to exchange information and update one another, which is likely to be costly in terms of decreasing productivity. The assumption also reflects profitability of availability. The more time an employee spends at the job, the more likely the employee is able to act immediately in case of emergencies and urgent requests. Arguments can furthermore be made in favor of learning by doing effects; the more time a worker spends producing, the more productive the worker becomes.

Total firm output per day, q , is the sum of output produced by each employee per day given as

$$q = A [e(l_1)l_1N_1 + e(l_2)l_2N_2], \tag{12}$$

where A is a positive productivity term, and $\frac{\partial q}{\partial N_i} = Ae(l_i)l_i$ is the marginal productivity of a worker i , which depends on the number of hours the worker puts into production. As l_i is taken as given, from the standpoint of the firm, the firm has constant returns to scale in employment. An implication of (11) in (12) is that longer hours worked at the firm lead to higher marginal productivity of labor as well as of workers.¹⁶

The firm decides how many workers to recruit in order to maximize its profits, π , which are the firm's revenues minus its costs. As the price of the market commodity is the numeraire, the profit maximization problem is to

$$\max_{N_1, N_2} \pi = \{A[e(l_1)l_1N_1 + e(l_2)l_2N_2] - w_1l_1N_1 - w_2l_2N_2\}. \quad (13)$$

Taking w_1, w_2, l_1 , and l_2 as given, in a competitive market, the firm employs workers until their marginal daily productivity, $Ae(l_i)l_i$, equalizes their marginal daily costs, $w_i l_i$. Hence,

$$\frac{\partial \pi}{\partial N_1} = Ae(l_1)l_1 - w_1l_1 = 0 \Leftrightarrow Ae(l_1) - w_1 = 0, \quad (14)$$

$$\frac{\partial \pi}{\partial N_2} = Ae(l_2)l_2 - w_2l_2 = 0 \Leftrightarrow Ae(l_2) - w_2 = 0. \quad (15)$$

Since labor, l_1 and l_2 , is measured in hours, the solution to the firm's problem depends on the relationship between hourly wages and effectiveness of an hour of labor at the firm adjusted by the productivity term A . In the following, we refer to $Ae(l_i)$ as the average productivity of labor per hour, $i = \{1, 2\}$. We have three different situations describing the firm's employment demand:

$$N_i = \begin{cases} \infty & \text{if } Ae(l_i) > w_i, \\ [0, \infty[& \text{if } Ae(l_i) = w_i, \\ 0 & \text{if } Ae(l_i) < w_i. \end{cases} \quad (16)$$

If $Ae(l_i) > w_i$ the firm would want to hire an infinite amount of type i workers, if $Ae(l_i) < w_i$ the firm would not want to hire any type i workers, and if $Ae(l_i) = w_i$ the firm is indifferent about the number of type i workers.

¹⁶Also in Becker (1985) and in Chichilnisky (2005) is marginal productivity of labor negatively related to labor used in the home.

3.3 Equilibrium

The conditions for existence of a competitive¹⁷ equilibrium in the economy involve: (i) the labor market, (ii) the market commodity, and (iii) the household service.

There are two types of equilibria. An *interior* equilibrium, in which the production levels of both x and z are strictly positive,¹⁸ and a *specialized* equilibrium, in which only one sector is producing.

An *interior* equilibrium involves a positive price vector, (w_1, w_2) , at which markets for male and female labor, as well as the market commodity and the household service clear; and for which the marginal conditions for an optimum given by the firm's and the family's first order conditions are satisfied.

There is a market clearing condition for each of the two goods. For every family, maximization of utility, (3)-(7), yields a labor allocation which satisfies

$$p_z z = \frac{b}{a} (t_1 t_2)^{\frac{\beta}{2}}, \quad (17)$$

so that household services consumed equal household services produced. Also the market commodity production must equal the market commodity demand. As the firm's production technology is linear homogenous in employment, we can normalize the number of firms to unity. In this case,

$$q = \bar{N}x \quad (18)$$

holds, where

$$q = A [e(l_1)l_1N_1 + e(l_2)l_2N_2] \quad \text{and} \quad \bar{N}x = \bar{N}(w_1l_1 + w_2l_2). \quad (19)$$

Finally, the employment clearing conditions are as follows. If there is a solution with a finite market commodity production, then from (16) we have that

$$Ae(l_i) = w_i \quad (20)$$

¹⁷The economy is competitive although there is the spillover effect from household service production to labor market productivity.

¹⁸Due to complementarity of male and female labor input in home production it follows that when home production is operative then $t_1 > 0$ and $t_2 > 0$. Moreover, as we prove in proposition 2 below, an equilibrium where only one spouse spends all time in home production does not exist. If instead, the household service could be produced separately by each adult, at least one individual would completely specialize in this sector. This result resembles Theorem 2.3 in Becker (1991, 34).

holds.¹⁹ Hence, (20) is a necessary condition for an interior competitive equilibrium. Together with the constant returns assumption on N_i (not on l_i), (20) implies that the competitive firm is indifferent about the number of workers it employs. In equilibrium, the number of female and male workers, N_1 and N_2 , equals the number of families \bar{N} ; i.e., $N_1 = N_2 = \bar{N}$.

Substituting (11) in (20) gives the following employment clearing conditions

$$Al_1 = w_1, \tag{21}$$

and

$$Al_2 = w_2. \tag{22}$$

In addition, productivity of an hour of labor equals the hourly wage. In the interior equilibrium, female and male labor supply equals female and male labor demand when (8) equals (21), and (9) equals (22). Using $l_i = \bar{T} - t_i$ we can derive two equations in t_1 and t_2 :

$$A(\bar{T} - t_1) = \frac{b}{a} \frac{\beta}{2} t_1^{\frac{\beta-2}{2}} t_2^{\frac{\beta}{2}}, \tag{23}$$

$$A(\bar{T} - t_2) = \frac{b}{a} \frac{\beta}{2} t_1^{\frac{\beta}{2}} t_2^{\frac{\beta-2}{2}}. \tag{24}$$

Eq. (23) and (24) states that in an equilibrium, average productivity of one hour of labor in the workplace has to equal the marginal value product of labor in home production.

We can now characterize an *interior* equilibrium as any combination of t_1 and t_2 which solves (23) and (24). Such a combination clears markets for male and female labor, and supports a price vector, (w_1, w_2) , for which also the market for x clears, and firms earn zero profits.

4 Results

In solving the model, it is useful to define a labor allocation for which $t_1 = t_2$ as *symmetric*, and one for which $t_1 \neq t_2$ as *asymmetric*. Both cases can occur,

¹⁹If $Ae(l_i) < w_i$ holds, production of the consumption good is zero, and if $Ae(l_i) > w_i$ holds, the firm earns positive profits.

but by (21) and (22), only an asymmetric situation leads to a gender wage gap. Specifically, we have

PROPOSITION 1 (*Symmetric equilibrium.*) *If $0 < \beta < 1$ and $\frac{b\beta}{a2A} < \left(\frac{\bar{T}}{2-\beta}\right)^{2-\beta} \times (1-\beta)^{1-\beta}$, then there exist two interior symmetric equilibria. If $\beta = 1$ and $\frac{b}{a2A} < \bar{T}$, then there exists one interior symmetric equilibrium.*

PROOF. See Appendix.

When $t_1 = t_2 \equiv t$, equations (23) and (24) collapse into

$$A(\bar{T} - t) = \frac{b\beta}{a2} t^{\beta-1}. \quad (25)$$

In equilibrium, the average productivity of an hour of labor in the firm equals the marginal value product of labor in home production as illustrated in fig. 3.

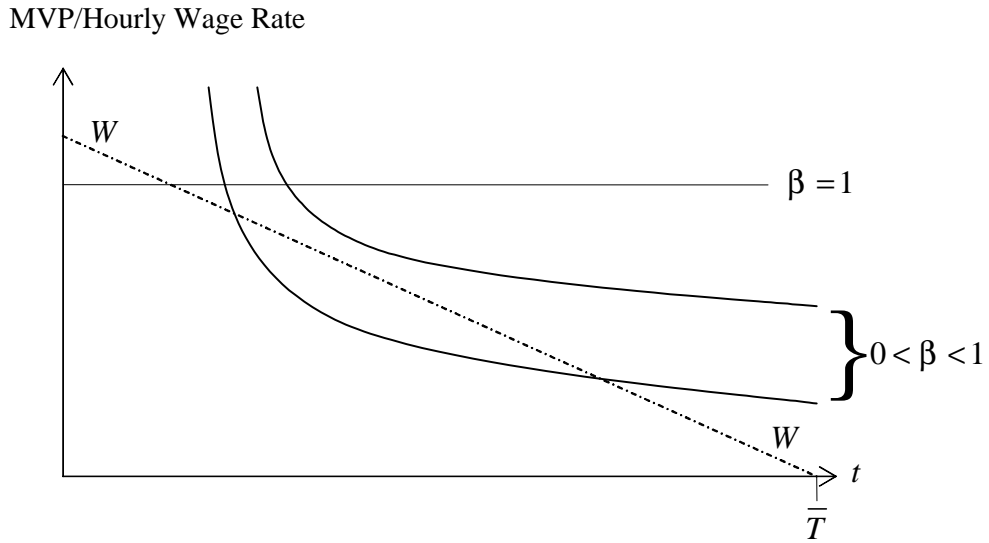


Figure 3: An illustration of symmetric equilibria. Symmetric equilibria exist in points where the hourly wage (illustrated by the dashed WW line) equals the marginal value product of labor in home production (illustrated by the solid lines). Spouses are in the same intersection point.

The dashed WW line in fig. 3 illustrates the hourly wage rate as a function of labor used in home production (i.e. t) which satisfies the zero profit condition in (16). Due to the negative spillover from household production onto productivity at the firm, the hourly wage decreases in t . The solid lines illustrate the marginal value product of labor in home production. The solid horizontal line illustrates the case where $\beta = 1$. The solid curved lines represent examples for $0 < \beta < 1$. The innermost curved line illustrates $\frac{b}{a} \frac{\beta}{2A} < \left(\frac{\bar{T}}{2-\beta}\right)^{2-\beta} (1-\beta)^{1-\beta}$ and the two intersections with the dashed WW line illustrate the two equilibria. The uttermost curved line illustrates a situation where $\frac{b}{a} \frac{\beta}{2A} > \left(\frac{\bar{T}}{2-\beta}\right)^{2-\beta} (1-\beta)^{1-\beta}$, which is an economy without an interior symmetric equilibrium, as the marginal value product of labor in home production exceeds the hourly wage rate for all allocations of labor resources. In this situation, only the home sector is operative.

Assume the hourly wage is such that it corresponds to one of the intersection points between the dashed WW line and the solid curved line in fig. 3. In this case, the firms are willing to hire workers, since marginal productivity just equals the marginal costs. Moreover, workers do not want to supply neither more nor less labor to the firm. If they supply more (i.e., decrease their labor input into home production), the marginal value product of labor in home production exceeds the given hourly wage rate. If they supply less (i.e., increase their labor input into home production), the marginal value product of labor in home production is less than the given hourly wage rate.

The intuition behind the existence of two symmetric equilibria can be explained as follows. When the household production function is concave in total labor input ($0 < \beta < 1$), for small t 's, the marginal value product of labor in home production is high and larger than the corresponding average productivity of an hour of labor in the firm, or equivalently, the hourly wage. As t increases, marginal productivity of labor in home production decreases to a point where it is exceeded by the hourly wage rate. As t becomes even larger, however, the negative spillover from home production onto average productivity at the firm increases further. Eventually, the spillover damages productivity to an extent that marginal value product of labor in

home production again exceeds the hourly wage rate.

Likewise, in the situation where $\beta = 1$, if the hourly wage rate coincides with the marginal value product of labor used in home production, the family is indifferent as to how much labor they supply to the firm. The firm, however, is only willing to hire labor when labor productivity is equal to, or higher than, the wage they must pay. To the left of the intersection point in fig. 3, however, firms would demand an infinite number of workers; therefore this cannot be an equilibrium. On the other hand, when $\frac{b}{a} \frac{1}{2A} > \bar{T}$, the marginal value product of labor in home production exceeds the hourly wage for all allocations of labor resources, and all labor is used in the home.

Similarly, we analyze the asymmetric equilibrium:

PROPOSITION 2 (*Asymmetric equilibrium.*) *If $\frac{b}{a} \frac{\beta}{2A} < \left(\frac{\bar{T}}{2}\right)^{2-\beta}$, then there exist two interior asymmetric equilibria.*

PROOF. See Appendix.

The asymmetric solution is illustrated by fig. 4. In fig. 4, again the dashed WW line illustrates decreasing hourly wages as a function of labor used in home production. The uttermost solid line illustrates the situation where $\frac{b}{a} \frac{\beta}{2A} > \left(\frac{\bar{T}}{2}\right)^{2-\beta}$; the situation without an interior solution. The innermost solid line intersects the dashed line twice, and illustrates the situation where husband and wife, despite being completely identical ex ante, allocate their labor endowments differently between the home and the workplace.

Whereas in the symmetric equilibrium, each spouse allocates the same labor to home production, and therefore an equilibrium is a situation where household members are “located” in the same intersection point of the two curves in fig. 3, the asymmetric equilibrium is an equilibrium, in which one family member is “located” in one intersection point and, simultaneously, the spouse is “located” in the other intersection point. In general, we have two possible pairings of gender and “location.” Household members may allocate labor according to traditional gender roles, or inversely.

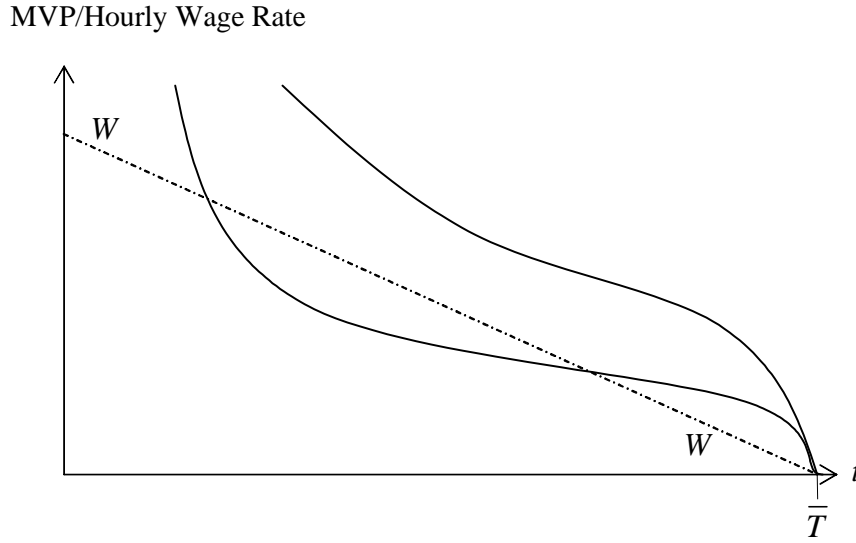


Figure 4: Asymmetric equilibria. Asymmetric equilibria are given by the pair of points where the hourly wage rate (illustrated by the dashed WW line) equals the marginal value product of labor in home production (illustrated by the solid lines). Household members are in *separate* intersection points.

PROPOSITION 3 (*Multiple interior equilibria.*) *If an interior asymmetric equilibrium is supported by a positive price vector (w_1, w_2) , there exists another price vector $(\tilde{w}_1, \tilde{w}_2) \neq (w_1, w_2)$ which supports an interior symmetric equilibrium.*

PROOF. See Appendix.

By proposition 3, we establish that for some sub-interval of the parameters A , a , and b , the model has multiple interior equilibria which results in either gender-similarities or gender-differences in labor allocation.

This result is important. It mirrors a self-fulfilling nature of expectations about gender roles. The family's efficient response to traditional beliefs about earnings is to actually allocate labor as stereotypical workers. On the other hand, the family's efficient response to unisex beliefs is to allocate labor identically. Proposition 3 suggests that the persistency in the gender wage gap relates to persistency in the

perception of the patterns of gender roles. We explore this issue further in detail in section 5, but first we notice that the model has interesting comparative statics for the asymmetric equilibrium.

PROPOSITION 4. *Assume the economy is in an asymmetric equilibrium. A higher productivity level A is associated with a larger gender wage gap.*

PROOF. See Appendix.

For a given initial asymmetric labor allocation, we consider a situation where A increases and, consequently, labor productivity in the firm goes up. The person with the lower t (the most labor allocated to the firm) experiences the highest increase in hourly wage as average productivity of an hour of labor increases in A at the rate $(\bar{T} - t)$.

As is clear from (10), the family's efficient labor allocation response to such a change in the relative hourly wage rates is that the person, who works most at the firm, allocates more labor to the firm, and the person, who works most at the home, allocates more labor to the home. Hence, the person who works most in the home ends up earning a lower wage than in the original equilibrium. In this way, increases in A magnify any existing differences productivity.

Assuming that couples predominantly exist within similar occupations,²⁰ Proposition 4 predicts that the gender wage gap is larger within families that work in sectors with higher wage rates. Fig. 5 is a scatter plot of female/male earnings ratio against male earnings for different occupations. Each dot in the scatter plot represents an occupation like civil engineers, lawyers, photographers, etc. If couples exist within similar occupations, then fig. 5 confirms proposition 4: the corresponding regression²¹ reveals a statistically significant negative relationship between male median weekly earnings and the gender wage ratio.

²⁰Some empirical evidence for educational homogamy, i.e., individuals marry individuals with similar characteristics such as occupation, education, and religion, is presented in Blossfeld and Timm (2003).

²¹The intercept estimate is 92.99 (38.66) and the slope estimate is -0.02 (-5.26), where the numbers in the parenthesis are the t -statistics. The fraction of the variation in the wage gap explained by the regression is above 20 percent (R^2 is 0.21).

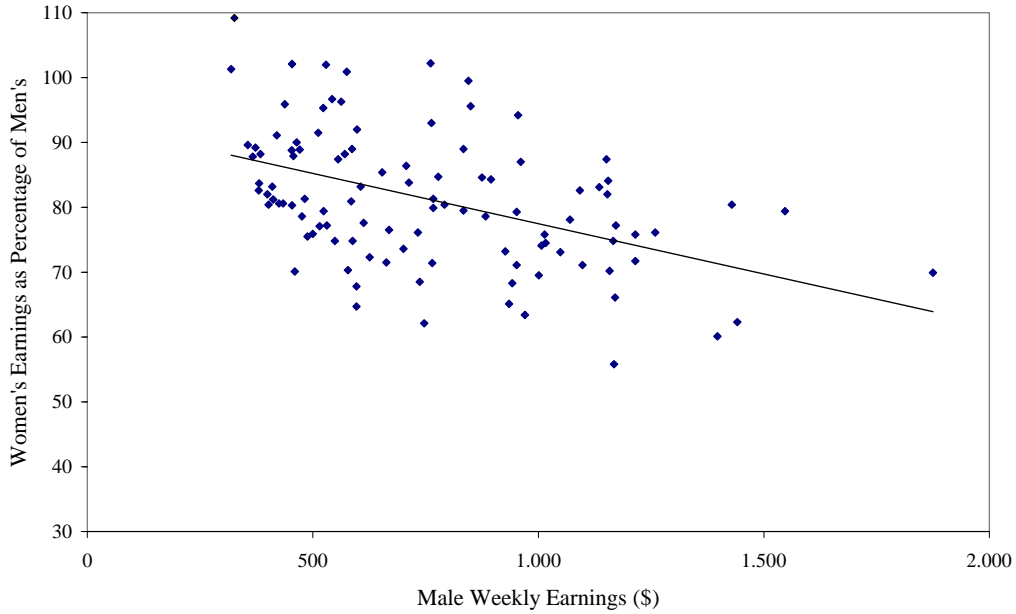


Figure 5: An illustration of the gender-differences in earnings across occupations in the US. The figure shows that higher male earnings within an occupation are correlated with a larger gender wage gap, i.e., lower women’s earnings relative to those of men’s. (Data from U.S. Department of Labor 2005, table 2.)

PROPOSITION 5. *Assume the economy is in an asymmetric equilibrium. A higher β reduces the gender wage gap if $\frac{b}{Aa} > \frac{2}{\beta} \exp\left(\frac{\beta-2}{\beta}\right)$.*

PROOF. See Appendix.

First, we analyze the situation where $\frac{b}{Aa} > \frac{2}{\beta} \exp\left(\frac{\beta-2}{\beta}\right)$ is satisfied. In this case, increases in β increase the marginal value product of labor in home production for both household members at given labor allocations. The increase is largest, however, for the person, who works less in the home. The benefit of letting the “outside working” work more in home production more than compensates for the loss of home production that the “home working” person sacrifices to enable the reallocation of labor.

Due to changes in the spillover effect from this reallocation of labor, also the equilibrium wage rates are affected. Since, in response to a high β , the “outside

working” person works less out, and “home working” person works less at home, the differences in productivities at the firm diminish, and in an equilibrium, wage rates are more equal.

The explanation for the opposite case, the situation where $\frac{b}{Aa} < \frac{2}{\beta} \exp\left(\frac{\beta-2}{\beta}\right)$, follows a similar logic. In this situation, however, the marginal value product declines instead of increases in response to increased β for the “outside working person.” Hence, the “outside working” person works even less in the home. The “home working person,” in turn, works more at home, as this person’s marginal value product of labor increases. The outcome is therefore a higher wage gap.

When the weight on the household service in the utility function, b , is low relative to the weight on the market commodity, a , the wage gap is more likely to increase in response to higher β . In this case, the initial labor allocation across spouses is already relatively specialized in an asymmetric equilibrium. In the limit, when t of one spouse approaches zero, increases in β diminish the marginal value product of this person’s labor in home production.

5 Welfare Analysis by Numerical Examples

The general public opinion typically favors gender equality on the labor markets and in the home (Hakim 2004), but according to Becker (1985), welfare increases with specialization. This result, however, is challenged in Chichilnisky (2005), as she finds that in a society with high skill levels, equal labor division across family members generates the highest welfare.

This section analyzes the welfare properties of the gender wage gap in the context of the present model. Let overall welfare in society, V , be given by the sum of household utilities and firm profits

$$V = \bar{N}u(x, z) + \pi = \bar{N}u(x, z), \tag{26}$$

where the last equality follows from firms earning zero profits in equilibrium. In the following, we can thus analyze utility levels of the representative family.

In order to be able to compare welfare levels across different types of equilibria, we proceed by use of numerical examples. Table 2 reports simulated symmetric equilibria, and table 3 reports simulated asymmetric equilibria.

Table 2 Simulated Symmetric Equilibria ($\bar{T} = 10$)

		t^a		x		z		$u(x, z)$	
$\frac{b}{Aa}$	β	t^l	t^h	l ^b	h ^c	l	h	l	h
10	0.3	0.07	9.69	197.21	0.19	0.45	1.98	201.71	19.96
10	0.6	0.05	8.74	198.01	3.18	0.17	3.67	199.66	39.90
10	0.9	0.00	6.25	200.00	28.13	0.00	5.20	200.00	80.16
15	0.3	0.12	9.54	195.23	0.42	0.53	1.97	203.17	29.93
15	0.6	0.14	8.05	194.44	7.61	0.31	3.50	199.05	60.03
15	0.9	0.02	4.15	199.20	68.45	0.03	3.60	299.65	122.44
20	0.3	0.18	9.37	192.86	0.79	0.60	1.96	204.82	39.93
20	0.6	0.30	7.26	188.18	15.02	0.49	3.29	197.89	80.72
20	0.9	0.90	1.00	165.62	162.00	0.91	1.00	183.81	182.00
13	0.9	0.01	5.02	199.60	49.60	0.02	4.27	199.81	105.14

^a Across the symmetric equilibria, t^l and t^h are the “low” and “high” equilibrium values, ($t^l < t^h$), of labor spent in home production

^b The label “l” indicates values which corresponds to t^l .

^c The label “h” indicates values which corresponds to t^h .

The first two rows in table 2 present different combinations of the parameters of the model. In the next columns, labor allocation is indicated by t^h and t^l respectively, where t^h is the labor allocation in which spouses allocate most labor to the home production, and t^l is the lowest ditto. Also production of the market commodity, x , of the household service, z , and welfare levels of the representative family, are indicated for both equilibria.

We notice that the family consumes different ratios of the household service and the market commodity across equilibria. Comparing welfare levels, however, we find, that utility is highest for the equilibrium in which spouses allocate most labor to the workplace, i.e., in $t = t^l$. This is partly due to the negative spillover effect of home production onto labor productivity at the firm. The extra production of the market commodity more than compensates for the decline in home production.

In table 3, we report the equilibrium in which women spend most time in the household.²² Therefore, the gender wage gap, ρ , is the wife-husband wage ratio. As in table 2, the first rows present different combinations of parameters.

Table 3 Simulated Asymmetric Equilibrium ($\bar{T} = 10$)

$\frac{b}{Aa}$	β	$t_1^a : t_2$	x	z	$u(x, z)$	ρ
10	0.3	9.84 : 0.16	96.85	1.07	107.56	0.00
10	0.6	9.49 : 0.51	90.32	1.60	106.37	0.00
10	0.9	8.10 : 1.90	69.22	3.42	103.43	0.06
15	0.3	9.73 : 0.27	94.75	1.16	112.08	0.00
15	0.6	9.05 : 0.95	82.81	1.91	111.41	0.01
15	0.9	- -	-	-	-	-
20	0.3	9.62 : 0.38	92.69	1.21	116.98	0.00
20	0.6	8.47 : 1.53	74.08	2.16	117.21	0.03
20	0.9	- -	-	-	-	-
13	0.9	5.42 : 4.58	50.35	4.24	105.51	0.71

^a In the asymmetric equilibrium, t_1 and t_2 denote the labor allocated to home production by the woman and the man respectively.

In the asymmetric equilibrium, the gender-difference in labor allocation is smaller when β is high. This is what we expect, since by proposition 5, when $\frac{b}{Aa} > \frac{2}{\beta} \exp\left(\frac{2-\beta}{\beta}\right)$ is fulfilled (which is the case when $\frac{b}{Aa} \in (10, 20)$), the wage gap is increasing in β . Table 3 also confirms proposition 4. A higher A increases the gender wage gap, i.e., decrease the wife-husband wage ratio.

To examine the welfare properties of the gender wage gap, we compare the asymmetric equilibrium with the symmetric equilibria. We find that production of the market commodity is higher everywhere in the symmetric equilibrium in which $t = t^l$ than in the asymmetric equilibrium. At the same time, however, production of the household service is higher in the asymmetric equilibrium than in this symmetric equilibrium. Yet the extra production in the formal sector makes up for the loss of household services and welfare is higher in the symmetric equilibrium. The simulations thus suggest that for the model presented in the present paper, a gender wage gap is Pareto inferior in that welfare in the symmetric equilibrium

²²The results equally apply to the reversed situation in which men are spending most time in the household.

(with least labor used in home production, i.e., $t = t^l$) is higher everywhere than welfare in the asymmetric equilibrium.

The explanation for this result is that when the economy is in an interior asymmetric equilibrium, home production suffers a productivity loss as family members are not allocating identical amounts of labor input. Since labor input of each spouse has identical factor shares, and since labor input is complementary in production, clearly the cost minimizing labor allocation in household production is when spouses allocate identical amounts of labor. Accordingly, in the symmetric equilibrium, total labor input in home production may be less and the asymmetric case (which is always equal to \bar{T} as $t_1 = \bar{T} - t_2$ cf. the proof of proposition 2) and yet produce more household service.

The last simulation in both tables offers a parameterization which gives a gender wage ratio which corresponds to the range of typical gender wage ratio estimates, cf. OECD (2002).

6 Discussion

Albeit the model does not provide a priori insight as to the specific equilibrium outcome among the possibilities of interior equilibria, a key prediction is that if families believe that wages are stereotype, the economy will experience a gender wage gap with women earning less than men. In this sense, the gender wage gap is explained as a self-fulfilling prophecy.

A natural way for today's families to decide on labor allocation would be to use information on "yesterday's" wages. If, for what could be historical and cultural reasons, women used to be less educated than men and to participate less in the labor force (cf. fig. 1) it would have been rational that women historically earned less than men. Hence, even though the premises, which determined the historical labor market outcome have changed, in that today, women and men share the same starting point to become equally productive in both the home and in the workplace, current beliefs about earnings may be "historically biased" in favor of stereotype

beliefs. This reasoning leads us to argue that persistence of the gender wage gap in developed societies can possibly be explained by a self-fulfilling “history bias” on beliefs.

An implication of this result is that family reality and family beliefs about earnings have to change simultaneously for the economy to move from the stereotype asymmetric equilibrium to a unisex symmetric equilibrium. Therefore, effective policies are policies that can change norms of society.²³ Without such policies the gender wage gap is likely to persist as a rational reaction to stereotype family beliefs about gender roles, even when there is no actual gender discrimination or other initial differences between genders.

In conformity with this analysis, table 4 demonstrates how gender roles are viewed within British families.

Table 4 Couples Aiming for Symmetric Roles

	Dual-earner ^a		Full-time Workers ^b	
	Men	Women	Men	Women
Percentage choosing symmetric roles	44	41	44	56

Source: Hakim (2004).

^aDual-earner couples refer to households in which either spouse reports being in employment.

^bFull-time workers couples consist of full-time working husbands and wives.

The numbers suggest that the majority of couples aim for traditional gender roles. Hakim (2004) argues that one explanation is that women regard themselves as secondary earners, and that employment does not provide them with their central identity.²⁴

Another explanation of why families do not change their traditional gender role perception can be that both men and women view equity as a relevant concept in

²³Chichilnisky (2005) argues that even if the economy is in the equal wage equilibrium, further policy measures are needed to prevent a Prisoner’s Dilemma game between the family and the firm, which leads to a stereotype equilibrium outcome, from evolving.

²⁴She also finds that families without children have a traditional division of labor.

the workplace, but neither view the home as a workplace. Roughly speaking, if housework is a “woman’s labor of love,” equity does not come into question. Moreover, men and women may define certain jobs as feminine and others as masculine. A woman is less of a woman if she does not keep the house, and the man is less of a man if he does. If men compare themselves to other men, and women to other women, and since the majority of households have unequal division of labor, both the woman or the man are likely to perceive traditional gender roles as normal and desirable (Hakim 2003; Valian 1999).

7 Concluding Remarks

Inspired by Becker (1985) and Chichilnisky (2005), this paper investigates the gender wage gap. In Becker (1985), spouses gain from a division of labor between employment and household work: one specializes in employment and the other specializes at home. Such a division raises the productivity of both persons in both sectors and a gender wage gap is Pareto efficient. Chichilnisky (2005) uses a logistic production function specification in both sectors, which changes from convexity to concavity through an inflection point. Within this framework, Chichilnisky (2005) shows that Becker’s Pareto efficiency result only holds for economies that are in the convex region, i.e., economies with a low skilled labor force. In economies which belong to the concave region, i.e., advanced economies, equal wages and equal labor allocation are Pareto efficient.

Like Becker (1985) and Chichilnisky (2005), we study an economy where male and female workers are *ex ante* identical except from gender. We show that changing the properties of the household production, so that it invokes complementarity of spousal labor in home production, while maintaining Becker’s specialization gains (what we refer to as indivisibility effects) of labor input in the workplace, may also lead to multiplicity of equilibria in which families’ beliefs about the gender wage gap are self-fulfilling. If family members believe that women earn less than men, *ex post*, intra-household labor allocation justifies such beliefs. We therefore argue

that women's past records on the labor market may have severe implications for the labor market outcome today, which are not easily overcome. Indeed, our welfare analysis reveals potential welfare gains to closing the gender wage gap. In this way, we show that the Pareto efficiency result in Chichilnisky (2005), also holds in a model where home production is Cobb-Douglas even when there are specialization gains in the firm sector.

Naturally, the approach to explaining the gender wage gap offered by the present model hopes just to offer a small piece of the gender wage gap puzzle. Besides the large literature that concerns differences in human capital accumulation, a literature largely initiated by Becker (1985), others have suggested that differences in wages can be attributed to a theory of "male-dominated institutions," or preference theory suggesting that women prefer to prioritize household tasks (Hakim 2004). Gender differences in networking (Montgomery 1991), and statistical discrimination (Moro and Norman 2003, 2004), may also lead to differences in wage rates.

A Appendix

A.1 Proof of Proposition 1

When $t_1 = t_2 \equiv t$, equation (23) and (24) collapse into

$$(\bar{T} - t)t^{1-\beta} = \frac{b}{Aa} \frac{\beta}{2}. \quad (27)$$

(This is eq. (25) in the main text.)

In general, a solution to (27) exists when the right hand side, which is parametrically given, is smaller than, or equal to, the maximum value of the left hand side.

When $\beta < 1$, the left hand side is an inversely ‘‘U-shaped’’ polynomial with a unique maximum that is positively skewed. The maximum is found by first differentiating the left hand side with respect to t , then setting this expression equal to zero, and finally isolate for t : $\frac{\partial(\bar{T}-t)t^{1-\beta}}{\partial t} = 0 \Rightarrow t^{-\beta} [\bar{T} - 2t + (t - \bar{T})\beta] = 0 \Leftrightarrow \bar{T} \left(\frac{1-\beta}{2-\beta} \right) = t$. Substituting this expression back into (27) determines the maximum value of the left hand side as of this equation a function of β ; $\arg \max_t (\bar{T} - t)t^{1-\beta} = \left(\frac{\bar{T}}{2-\beta} \right)^{2-\beta} (1-\beta)^{1-\beta}$. Hence, in an interior equilibrium $\frac{b}{Aa} \frac{\beta}{2} \leq \left(\frac{\bar{T}}{2-\beta} \right)^{2-\beta} (1-\beta)^{1-\beta}$ must be satisfied. When the equation holds with equality, there is exactly one solution, otherwise there are two solutions.

When $\beta = 1$ the left hand side of (27) is linear and equal to $(\bar{T} - t)$. Hence, the maximum is given when $t = 0$, so $\arg \max_t (\bar{T} - t) = \bar{T}$. For an interior equilibrium to exist, $\frac{b}{a} \frac{1}{2A} < \bar{T}$. \square

A.2 Proof of Proposition 2

An interior equilibrium is given when (23) and (24) are satisfied simultaneously. Dividing (23) and (24) means $\frac{\bar{T}-t_1}{\bar{T}-t_2} = \frac{t_2}{t_1}$ must hold. Rewriting this expression yields $\bar{T}t_1 - t_1^2 = \bar{T}t_2 - t_2^2 \Leftrightarrow \bar{T}(t_1 - t_2) = t_1^2 - t_2^2 \Leftrightarrow \bar{T}(t_1 - t_2) = (t_1 + t_2)(t_1 - t_2) \Rightarrow t_1 + t_2 = \bar{T}$ for $t_1 \neq t_2$.

Substituting $t_1 = \bar{T} - t_2$ back into either (23) or (24), rearrange and solve for t_2

gives

$$(\bar{T} - t_2)t_2 = \left(\frac{b}{Aa} \frac{\beta}{2} \right)^{\frac{2}{2-\beta}}. \quad (28)$$

Eq. (28) is a second-order polynomial. By inspection we find that the shape of the left hand side is a symmetric parabola for which $\arg \max_{t_2} (\bar{T} - t_2)t_2 = \left(\frac{\bar{T}}{2} \right)^2$. The left hand side is a constant larger than zero. If $\frac{b}{Aa} \frac{\beta}{2} > \left(\frac{\bar{T}}{2} \right)^{2-\beta}$, then there is no solution to (28), and if $\frac{b}{Aa} \frac{\beta}{2} = \left(\frac{\bar{T}}{2} \right)^{2-\beta}$, then there is one solution ($t_1 = t_2 = \frac{\bar{T}}{2}$), and if $\frac{b}{Aa} \frac{\beta}{2} < \left(\frac{\bar{T}}{2} \right)^{2-\beta}$, then there are exactly two solutions satisfying $t_1 \neq t_2$. \square

A.3 Proof of Proposition 3

By proposition 1, $\frac{b}{Aa} \frac{\beta}{2} \leq \left(\frac{\bar{T}}{2-\beta} \right)^{2-\beta} (1-\beta)^{1-\beta}$ and $\frac{b}{Aa} \frac{1}{2} < \bar{T}$ are necessary conditions for an interior symmetric equilibrium when $0 < \beta < 1$ and when $\beta = 1$ respectively. The interior symmetric equilibrium is supported by a positive price vector which we denote $(\tilde{w}_1, \tilde{w}_2)$. By proposition 2, $\frac{b}{Aa} \frac{\beta}{2} < \left(\frac{\bar{T}}{2} \right)^{2-\beta}$ is a necessary condition for an interior asymmetric equilibrium, which is supported by another price vector which we denote (w_1, w_2) .

We want to prove that when there exists an asymmetric equilibrium, then there also exists a symmetric equilibrium, i.e., that

$$\left(\frac{\bar{T}}{2} \right)^{2-\beta} \leq \left(\frac{\bar{T}}{2-\beta} \right)^{2-\beta} (1-\beta)^{1-\beta} \quad \forall \quad 0 < \beta < 1, \quad (29)$$

and

$$\left(\frac{\bar{T}}{2} \right) \leq \bar{T} \quad \forall \quad \beta = 1. \quad (30)$$

We prove each in turn. First, simplify (29) to get

$$\left(\frac{1}{2} \right)^{2-\beta} \leq \left(\frac{1}{2-\beta} \right)^{2-\beta} (1-\beta)^{1-\beta}.$$

Let $LHS \equiv \left(\frac{1}{2} \right)^{2-\beta}$ and $RHS \equiv \left(\frac{1}{2-\beta} \right)^{2-\beta} (1-\beta)^{1-\beta}$. We examine LHS and RHS for $\beta \rightarrow 0$ and $\beta \rightarrow 1$ respectively.

$$\begin{aligned} LHS_{\beta \rightarrow 0} &= \frac{1}{4} \quad \text{and} \quad LHS_{\beta \rightarrow 1} = \frac{1}{2}, \\ RHS_{\beta \rightarrow 0} &= \frac{1}{4} \quad \text{and} \quad RHS_{\beta \rightarrow 1} = 1. \end{aligned}$$

Hence, in the limits $RHS \geq LHS$. In order to study monotonicity, we first take logs:

$$\begin{aligned}\ln(LHS) &= (2 - \beta) \ln\left(\frac{1}{2}\right), \\ \ln(RHS) &= (1 - \beta) \ln(1 - \beta) + (\beta - 2) \ln(2 - \beta),\end{aligned}$$

and then we take the derivative with respect to β :

$$\begin{aligned}\frac{\partial[\ln(LHS)]}{\partial\beta} &= \ln(2) > 0, \\ \frac{\partial[\ln(RHS)]}{\partial\beta} &= -\ln(1 - \beta) + \ln(2 - \beta) > 0.\end{aligned}$$

Hence, both sides of (29) are monotonically increasing. Furthermore,

$$\begin{aligned}\frac{\partial^2[\ln(LHS)]}{\partial\beta^2} &= 0, \\ \frac{\partial^2[\ln(RHS)]}{\partial\beta^2} &= \frac{1}{(1 - \beta)(2 - \beta)} > 0.\end{aligned}$$

We can thus conclude, that if an interior asymmetric equilibrium exists, then also an interior symmetric equilibrium exists for $0 < \beta < 1$.

Second, simplify (30) to get

$$\frac{1}{2} \leq 1,$$

which is true. \square

A.4 Proof of Proposition 4

From the proof of proposition 2, we have that an interior asymmetric equilibrium must satisfy

$$(\bar{T} - t_2)t_2 = \left(\frac{b\beta}{Aa2}\right)^{\frac{2}{2-\beta}}, \quad (31)$$

where $\bar{T} - t_2 = t_1$.

Differentiate the right hand side with respect to A to get

$$\frac{\partial\left(\frac{b\beta}{Aa2}\right)^{\frac{2}{2-\beta}}}{\partial A} = \left(\frac{b\beta}{a2}\right)^{\frac{2}{2-\beta}} \left(\frac{2}{\beta-2}\right) A^{\frac{2}{\beta-2}-1} < 0,$$

which means that an increase in A shifts down the right hand side of (31).

The left hand side of (31) is an inverted “U-shaped” parabola, and therefore the distance between the values of $(\bar{T} - t_2)$ and t_2 which solves the system increases as A increases.

The wage gap is given as a function of t_2 and t_1 by (10): $\frac{w_1}{w_2} = \frac{t_2}{t_1}$. The more t_1 and t_2 differs, the higher the gender wage gap. \square

A.5 Proof of Proposition 5

From the proof of proposition 2, we have that an interior asymmetric equilibrium must satisfy

$$(\bar{T} - t_2)t_2 = \left(\frac{b}{Aa} \frac{\beta}{2} \right)^{\frac{2}{2-\beta}} \quad (32)$$

where $\bar{T} - t_2 = t_1$.

In order to analyze the effect of a change in β we take logs on both sides of this equation:

$$\ln(\bar{T} - t_2) + \ln(t_2) = \frac{2}{2-\beta} \left[\ln \left(\frac{b}{2Aa} \right) + \ln(\beta) \right].$$

The left hand side does not depend on β . For the right hand side we find that

$$\frac{\partial \left\{ \frac{2}{2-\beta} \left[\ln \left(\frac{b}{2Aa} \right) + \ln(\beta) \right] \right\}}{\partial \beta} = \frac{2}{2-\beta} \left\{ \frac{1}{2-\beta} \left[\ln \left(\frac{b}{2Aa} \right) + \ln(\beta) \right] + \frac{1}{\beta} \right\}.$$

As $0 < \beta \leq 1$, $\ln(\beta)$ is non-positive, and $\ln \left(\frac{b}{2Aa} \right) < 0$ if $\frac{b}{2Aa} < 1$, we can conclude that $\frac{\partial \left\{ \frac{2}{2-\beta} \left[\ln \left(\frac{b}{2Aa} \right) + \ln(\beta) \right] \right\}}{\partial \beta} > 0$ only if $\frac{b}{Aa} > \frac{2}{\beta} \exp \left(\frac{\beta-2}{\beta} \right)$. Again, the left hand side of (32) is an inverted “U-shaped” parabola, and therefore the distance between the values of $(\bar{T} - t_2)$ and t_2 which solves the system decreases as β increases when $\frac{b}{Aa} > \frac{2}{\beta} \exp \left(\frac{\beta-2}{\beta} \right)$.

The wage gap is given as a function of t_2 and t_1 by (10): $\frac{w_1}{w_2} = \frac{t_2}{t_1}$. The more t_1 and t_2 differs, the higher the gender wage gap. \square

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CHAPTER 2

Empirics of Economic Growth and Natural Resources

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Abstract

During recent decades, the notion of a resource curse seems to have become increasingly widespread among economists. Yet endogenous growth theory generally suggests that greater endowments provide better opportunities for economic growth. Theory alone, however, cannot tell us, a priori, if or when natural resources are a curse. We examine recent empirical work to answer the following questions: How is natural resource abundance correlated with economic growth? In particular, does it matter what types of natural resources are considered, and does it matter how natural resources are measured? What are the pathways through which natural resources impact growth? In addition, we present a simple cross sectional analysis which suggests that the size of the combined agricultural and forestry industry relative to GDP is negatively correlated with growth, whereas neither the size of the mining industry nor of the fishing industry relative to GDP seems to have any systematic relationship with growth.

Key Words: Natural Resources, Natural Resource Classification, Economic Growth

JEL Classification Codes: O13, O40, Q2, Q3

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1 Introduction

The role of natural resources in economic development and economic growth is the subject of a large literature that roughly can be grouped into two. One strand is concerned with neo-Malthusian topics: Can humankind sustain current consumption and welfare levels as the natural environment gets further depleted? The other strand is concerned with topics that relate to the idea of a resource curse: Can a diametrical relationship between economic growth and natural resource abundance be avoided?

The focus of this paper is on the second subject, and, in particular, on what can be concluded from the growing body of empirical work. It appears, as Wright and Czelusta (2002, 2) put it, that “resource-based economic growth has had a bad press for some time.” Yet the large variation in how natural resources are measured, in what types of natural resources are considered, and in how natural resources are suggested to interfere with growth, complicates cross-study comparisons. Therefore, the purpose of this paper is to offer a comprehensive review of recent empirical results. Especially, we seek to answer the following questions: How is natural resource abundance correlated with economic growth? In particular, does it matter what types of natural resources are considered, and does it matter how natural resources are measured? What are the pathways through which natural resources and growth are potentially correlated?

We find, based on a survey of 17 studies, that more studies show evidence that point resources (resources with a high value concentration) are negatively correlated with growth than evidence that diffuse resources (resources with a scattered value concentration) are negatively correlated with growth. Almost all studies that examine non-differentiated resources, i.e., all primary products, find a negative relationship between growth and natural resource abundance.

An important factor in these results, however, seems to be how natural resource abundance is measured. Measured in relative terms, such as relative to the overall size of the economy, natural resources seem consistently negatively correlated with

growth performance. In sharp contrast to this result, is the little empirical evidence to support that absolute levels of natural resources have a negative impact on growth.

Pathways that link natural resources and economic growth are numerous. Point resources appear to cast their curse through weakened human capital accumulation, damaged institutional quality, increased debt, and worsened terms of trade, but, at the same time there is also evidence that point resources bless growth through better institutional quality. Also diffuse resources are found to both harm and benefit institutional quality.

This survey of the resource curse literature is not the first of its kind. Stevens (2003) provides an excellent review of the literature with special attention to theories of transmission mechanisms, and Wright and Czelusta (2004) scrutinize the idea of a resource curse by means of historical and case-based evidence, focusing, however, purely on mineral resources. The present paper, in contrast, draws only sporadic links to the theoretical literature and does not have a historical perspective beyond that of the period in which growth is examined; which typically means the last half of the twentieth century. Instead, the aim is to collect and organize recent empirical evidence in a manner so that the resource curse or perhaps the lack hereof, can be characterized. We limit the scope of the analysis to the question of whether the resource impact has a positive, a negative, or no correlation with growth; the magnitude of the impact is not considered.

To supplement the survey, we look at data. Specifically, we examine how the value added by different natural resource industries relative to GDP is correlated with economic growth. We find that size of the combined agricultural and forestry industry relative to GDP is negatively correlated with growth performance, whereas neither the relative size of the mining nor the fishing industry seems to have any systematic impact on growth. These results are in conformity with a few studies included in the survey, but seem to diverge from the “general pattern.” A general pattern of how various types of natural resources impacts growth, however, is not easily established.

The paper proceeds as follows. The next section presents further motivation for why an appraisal of different natural resource types and measures of natural resource abundance is likely to be an important tool in unraveling if, and how, natural resources are correlated with growth. In section 3, we survey 17 empirical studies on the resource curse after first establishing their relationship to earlier empirical results. We pay special attention to how natural resources are measured and how they interact with growth. On this basis, we report stylized results of the resource impact in section 4. Section 5 presents our empirical analysis, and the final section provides concluding remarks.

2 Natural Resource Measures and Types

At least two immediate tasks arise in the attempt to empirically examine the resource curse: the first is to decide which measure to use for natural resource abundance, and the second is to clarify the type of the natural resource(s) under suspicion.

2.1 How to Measure Natural Resource Abundance?

The empirical literature typically measures natural resource abundance in two ways: either by the value of production (or exports) of natural resources relative to GDP (or exports), or by absolute levels of production, exports, or reserves. In the following we refer to the first measures as proxies of relative natural resource abundance, and to the latter measures as proxies of the absolute natural resource abundance:

Relative abundance measure:

natural resources measured relative to the size of the economy or exports.

Absolute abundance measure:

natural resources measured as endowments, reserves, or production.

Stijns (2005, 110) notes: “there is no theoretical reason to believe that results obtained by using one type of resource abundance indicator would necessarily extend the results reached using another type of such indicator.”

The likely importance of this dichotomy can be motivated by a simple illustration. Durlauf et al. (2005) identify 15 “growth miracles” and 15 “growth disasters.” The growth miracles are the countries which in 1960-2000 have had the highest annual growth rate, and the growth disasters are the countries with the lowest ditto. Table 1 presents the growth estimates of Durlauf et al. (2005) along with each nation’s per capita natural resource wealth divided into six natural resource types as estimated by World Bank (2006).¹

The last column presents all natural resource wealth in total wealth. Median and the average values for each group of countries are also calculated and included in the table. One difference in the natural resource abundance pattern between the two groups of countries is striking: as a share of total wealth, the growth miracles have substantially less natural resource wealth than the growth disasters. On average, growth miracles have eight percent of all their wealth in natural resources, whereas growth disasters have on average seven times as much: 43 percent. Yet no differences in the endowments of the individual resources between the two groups appear distinct. The most valuable natural resource for the growth miracles is cropland and pastureland; forest resources and protected areas play a smaller role. There is substantial variation in whether growth miracles have subsoil assets, but, on average, subsoil assets are their third largest source of natural wealth.

Also the group of growth disasters has substantial wealth in cropland and a large variation in subsoil assets. The median subsoil wealth of this group is less than the median subsoil wealth of the growth miracles, and five countries have no subsoil wealth compared to only four countries in the growth miracles group. In addition, the median growth disaster country has less natural resource wealth than the median growth miracle country.

¹Unfortunately, World Bank (2006) estimates are incomplete for two of the biggest growth winners: Taiwan and Hong Kong, and for two of the biggest growth losers: Congo and Angola.

Table 1 Annual Growth and Per Capita Natural Resource Wealth in 2000

	Growth								
	1960-2000	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Taiwan	6.3	0	0	-	0	-	-	-	-
Botswana	6.1	246	172	1681	299	55	730	3183	8
Hong Kong	5.7	0	0	-	0	0	0	-	-
Korea, R.	5.4	33	0	30	441	1241	275	2020	1
Singapore	5.1	0	0	0	0	0	0	0	0
Thailand	4.5	469	92	55	855	2370	96	3936	11
Cyprus	4.3	32	7	67	0	1757	929	2794	-
Japan	4.1	28	38	56	364	710	316	1513	0
Ireland	4.1	385	222	51	172	1583	8122	10534	3
China	4.0	511	106	29	27	1404	146	2223	24
Romania	3.9	1222	290	65	175	1602	1154	4508	15
Mauritius	3.9	0	0	3	0	577	62	642	1
Malaysia	3.8	6922	438	188	161	1369	24	9103	19
Portugal	3.5	41	438	107	385	1724	934	3629	2
Indonesia	3.3	1549	346	115	167	1245	50	3472	25
Mean (growth miracles)		763	143	188	203	1117	917	3658	8
Median (growth miracles)		41	92	56	167	1307	210	3183	3
Peru	0.0	934	153	570	98	1480	341	3575	9
Mauritania	-0.1	1311	14	29	21	1128	480	2982	37
Senegal	-0.3	4	238	147	78	608	196	1272	13
Chad	-0.4	0	311	366	80	787	316	1861	42
Mozambique	-0.5	0	340	392	9	261	57	1059	25
Madagascar	-0.6	0	174	171	36	955	345	1681	33
Zambia	-0.6	134	276	716	78	477	98	1779	27
Mali	-0.8	0	121	276	44	1420	295	2157	41
Venezuela	-0.9	23302	0	464	1793	1086	581	27227	60
Niger	-1.0	1	9	58	152	1598	187	1975	53
Nigeria	-1.2	2639	270	24	6	1022	78	4040	147 ^{a)}
Nicaragua	-1.3	9	475	146	184	867	410	2092	16
C. Afr. R.	-1.6	0	427	1397	641	839	370	3673	61
Angola	-2.0	5602	306	1276	31	395	204	7813	-
Congo	-4.0	0	0	-	5	278	7	-	-
Mean (growth disasters)		2262	208	429	217	880	264	4513	43
Median (growth disasters)		4	238	321	78	867	295	2124	37

Source: Durlauf et al. (2005) and World Bank (2006).

Note: (1): Subsoil assets; (2): Timber resources; (3): Non-timber forest product; (4): Protected areas; (5): Cropland; (6): Pastureland; (7): All natural wealth; and (8): All natural wealth as percentage of total wealth (The sum of natural, produced and intangible wealth). Figures in (1)-(7) are in dollars per capita and in (8) in percent.

^{a)}Natural wealth can exceed total wealth when another wealth component, intangible capital, is negative. For a detailed explanation, consult World Bank (2006, ch. 2).

Thus, this simple illustration suggests that the growth disasters are not characterized by high absolute natural resource endowments, but rather by a high share of natural resource wealth in total wealth, i.e., high relative natural resource abundance.²

Among the 17 studies included in this survey, most use a relative natural resource abundance measure. As some studies discuss, this measure may, however, suffer from endogeneity problems: high relative natural resource abundance can be a result of general underdevelopment. The following example is taken from Ng (2006, 2): “Suppose there is an exogenous time-invariant factor called institutional quality, which has a positive effect on GDP growth but a negative impact on natural resource exports. Over a long time horizon, countries with poor institutional quality will exhibit lower GDP levels and higher resource exports than those with better institutional quality. Therefore, the resource dependency ratio . . . in the former countries will be higher than that in the latter countries. If we use the resource dependency ratio as a proxy for resource abundance, then we would tend to find a negative correlation between output growth and resource abundance. But this negative relationship is driven by institutional quality, and not by natural resource abundance.”

A similar concern is shared by Stijns (2005). He (*ibid.*, 108) argues that measuring natural resource abundance by relative abundance is an issue of concern in that relative abundance, and Stijns quotes Wright (2001), “may serve primarily as proxies for development failure, for any number of reason that may have little to do with the character of the resources themselves.”

2.2 How to Classify Natural Resource Types?

Whereas a part of the empirical literature treats natural resources as one aggregate resource, others distinguish between different types of natural resources. This section provides a brief guide to different ways natural resources can be classified in

²Heal and Chichilnisky (1991, 103) make a related observation. They argue that nations which have a high share of oil in GDP (e.g., Middle-East nations) have a growth pattern that replicates the pattern of the oil price.

relation to economic development.

Generally, a commodity is considered a natural resource when the primary activities associated with it are extraction and purification. Thus, mining, petroleum extraction, fishing, and forestry are natural resource industries. Often, however, the definition of natural resources is more casual and refers to all primary products, and includes also agriculture and horticulture industries such as in the recent World Bank (2006) statement of the wealth of nations, in which, natural resources are divided into six different groups: subsoil assets, timber resources, non-timber forest products, protected areas, cropland, and pastureland.

A classical natural resource type classification is based on *availability*: the distinction between renewable and non-renewable resources. Renewable resources are regenerated within a time span relevant to man,³ such as timber, fish, wildlife, and agricultural produce, whereas non-renewable resources are not, such as oil, gas, coal, and diamonds. This property conditions how a particular natural resource is optimally exploited and managed,⁴ and is at the core of a large literature on sustainability.⁵ A central aspect of renewable resources is that overextraction prevents regeneration and causes deterioration. This can be fatal to the economy and was arguably the reason behind the collapse, a complete growth disaster, of the Easter Island civilization around 1400 A.D. as demonstrated by Brander and Taylor (1998).

Overextraction problems of natural resources, also known as the “tragedy of the commons,” can in addition be related to the *institutional* properties of the resource. Institutional properties concern whether the resource is excludable or non-excludable. The degree of excludability is determined by existence and enforcement of property rights. Classical non-excludable resources are common grazing land and the stocks of fish and wildlife. Chichilnisky (1994) argues that poorly defined property rights on natural resources in resource rich poor countries may (falsely)

³Assuming sustainable harvest methods that allow regeneration.

⁴See, e.g., Dasgupta and Heal (1979).

⁵The sustainability literature especially emphasizes that considerations of the well-being of future generations should play an important role in how natural resources, in particular, non-renewable resources, are managed today (Hartwick 1977; Solow 1986).

look like a comparative advantage in resource intensive goods. Trade between such countries and countries with well defined property rights leads to over-extraction of the natural resource.

In the context of the resource curse literature, a problem with the *institutional* property classification is that while in principle a resource can be assigned property rights, in practice, the cost of enforcing those property rights can be extremely high due to massive contest from rent seekers. This additional consideration speaks in support of a classification system which is based on how easily a resource can be *appropriated*.

Appropriability in part depends on the institutional properties and in part on the availability properties of the resource: A number of renewable resources are spread over large geographical areas, which makes it difficult to enforce an ownership; i.e., tend to make them non-excludable. In turn, however, their value is scattered over large areas and thus they are poor targets for rent seeking. This type of natural resources is therefore also called *diffuse* resources. *Point* resources, in turn, are concentrated in narrow geographical areas; e.g., non-renewable resources such as minerals and oil, but also plantation produce such as timber, sugar, and banana. In contrast to diffuse resources, point resources have high values concentrated in small areas and they are consequently easy targets for rent seeking, corruption, and conflicts.⁶

3 The Empirical Literature

The notion of a “resource curse” is not new; it dates back in history. The decline of Spain’s prosperity after its colonization of the New World and discovery of large amounts of gold and other precious metals is a classical example. And even before this era, philosophers were concerned over “the impact of great wealth on a society” (Stevens 2003, 5). Yet it is apparently not until after World War II that the economics literature begins to argue that there may be a systematic negative rela-

⁶For a detailed classification of natural resources in relation to conflicts, consult Lujala (2003) and Boschini et al. (2005).

tionship between natural resource abundance and economic performance.⁷ And it is not until even later that empirical evidence, which suggests a negative connection between natural resource abundance and economic growth, emerges. Chichilnisky and Heal (1986, 43) present evidence that, in the period 1973-1982, middle-income oil exporters on average grew less than middle-income oil importers. In some years, 1960-70, however, the situation was reversed. This finding is explained within a North-South trade model, originally presented in Chichilnisky (1981). By examining the situation where the South is characterized by duality in production (i.e., large variation in factor input ratios across sectors) and abundant labor (i.e., a highly elastic labor supply), Chichilnisky shows that increased export by the South may lead to worsened terms of trade and less growth the South. If one interprets the “basic good” as a natural resource, the model predicts a resource curse type of situation. Indeed, the model is extended in this direction in subsequent work. For instance, Chichilnisky et al. (1984) introduce oil as a separate factor input which is exported by the South. In order to produce the oil, the South needs a financial transfer. The paper illustrates that when the South expands its oil sector, by borrowing foreign capital, the terms of trade can be worsened for the South (the opposite may also happen). In succeeding work, which among others includes Heal and Chichilnisky (1991), the growth performance of oil-exporting countries relative to that of oil-importing countries is further scrutinized. In addition to the pattern already explained in Chichilnisky and Heal (1986), the authors observe that high-income oil exporters went from having the highest growth rate in 1973 to the slowest growth rate in 1982. Chichilnisky and Heal (*ibid.*, 103-4) argue that a possible explanation is that high-income oil exporters have a high relative share of natural resource (oil) revenues in GDP, and hence these economies “followed the fate of the oil sector. The oil sector, in turn, followed the fate of oil prices.”

Another early contribution to the empirical evidence relating to the resource

⁷Initially concern was with the impact that exports of primary products could have on the terms of trade and the lack of linkages generated by primary product exports compared to those of manufacturing. Following the oil-shocks in the 1970s, also theoretical literature on the Dutch disease begins to emerge. For a detailed review of these theories, consult Stevens (2003).

course is Auty (1993). Auty also finds that in 1960-83, on average, mineral and oil exporters had lower growth rates than “other middle-income” countries. Focusing in particular on selected mineral economies, Auty argues, among other things, that an overconfidence in the ability of the mineral sectors to spur future economic development prevented development of a “competitive economic diversification.”

The current generation of resource curse literature is largely sparked by the influential papers of Sachs and Warner (1995, 1997)⁸ in which the authors observe what they call a “conceptual puzzle”; namely, that natural resource abundance seems to have adverse effects on growth. While the earlier literature has already hinted at a negative relation between natural resource abundance and economic growth, Sachs and Warner appears to be the first who, in order to compare the role of natural resource abundance in economic growth across a large number of countries, perform a cross sectional analysis.⁹ Since then, more studies on the resource curse have followed this approach. We limit the scope of our survey to empirical work produced after Sachs and Warner (1995, 1997), and to empirical results which stem from cross sectional regressions.¹⁰ Hence, common to all studies in this survey is that they have annual growth in GDP per capita, or per economically active population, as dependent variable,¹¹ and some measure of natural resource abundance among the independent variables. Special emphasis is put on examining how natural resource abundance is correlated with economic growth; what types of natural resources are considered; how natural resources are measured; and on identifying the pathways through which natural resources and growth are potentially correlated.

Each study is in the following grouped according to the particular pathway which

⁸Sachs and Warner (1997) is essentially an updated version of Sachs and Warner (1995).

⁹In the context of Barro (1991).

¹⁰In practice, this means we omit results from panel estimations in our survey. Among the 17 studies which we review, the few studies that consider panel estimations, however, also report cross sectional results.

¹¹Although it has been argued by Neumayer (2004) that this is to “analyze the wrong term.” Instead he suggests that growth in genuine income, i.e., “GDP minus the depreciation of produced and natural income,” is the right measure. Neumayer finds, than genuine income growth and natural resource abundance appears to be negatively correlated too. In fact, the resource curse seems somewhat more severe for genuine income growth than for GDP growth.

relates natural resource abundance to growth: Dutch disease; institutions, conflicts, and social infrastructure; other pathways; and no pathways. Some papers have a theoretical model to motivate their empirical approach, whereas others purely focus on the empirics. In addition to the general survey below, table A1 in the appendix provides a list of the selected 17 studies contained in our survey, along with information about the growth period considered and the sample sizes used by each study.

3.1 Dutch disease

Theories of Dutch disease generally focus on explaining a negative relationship between natural resource abundance and productivity levels, appreciation of the real exchange rate, and declining growth rates (e.g., Corden and Neary 1982; van Wijnbergen 1985; Krugman 1987; Torvik 2001; Frederiksen 2007).

3.1.1 Sachs and Warner (1995, 1997)

In their seminal paper, Sachs and Warner (1995, 1997) consider a theoretical Dutch disease model in which learning by doing is purely generated in the manufacturing (traded) sector. An increase in resource intensity leads to increased demand for non-traded goods and accordingly to a movement of labor from the traded sector into the non-traded sector. As the traded sector shrinks, subsequent growth rates decline.

In their empirical analysis, Sachs and Warner examine the relationship between natural resource abundance and growth. Natural resources are defined in the broad sense as primary products and measured by a measure of relative natural resource abundance: *the ratio of primary product exports to GNP (SXP) in 1970*. Including a number of variables, such as initial income, institutional quality, openness, inequality, terms of trade volatility, and investments in their growth regression, SXP remains significant and negative. As a robustness test of the measure of natural resource abundance, Sachs and Warner also consider: the share of mineral production in GDP in 1971, the fraction of primary exports in total exports in 1971, and

the log of land area per person in 1971; all of which also seem to be negatively associated with subsequent growth.

As an attempt to unravel how natural resources exercise their impact on growth, Sachs and Warner examine if natural resources, besides the direct impact, have an indirect impact that works through the control variables. It seems, however, that the evidence of any indirect effects is vague, and, in magnitude, less important than the direct effects. Accordingly, their analysis appears to demonstrate that natural resource abundance belongs to the list of variables which have a direct negative impact on growth.

Sachs and Warner (1995, 1997) offer little insight into how this relationship can be explained. An interpretation near at hand is therefore that natural resources are bad for growth per se. Sachs and Warner stress, however, that this would be a misinterpretation and warn against precipitate discrimination against natural resource industries.

3.1.2 Gylfason, Herbertsson, and Zoega (1999)

Gylfason et al. (1999) also present a theoretical Dutch disease model. Their hypothesis is that the size of the primary sector influences growth negatively by preventing a “secondary” traded sector, in which all learning by doing is generated, to expand. To test this theory empirically, as their measure for natural resource abundance, they use *the share of primary production in the labor force* in 1970. Controlling for initial income, investments, primary and secondary education, external debt, exchange rate volatility, and using an African dummy, they find that the size of the labor force in the primary sector is negatively (albeit only significantly when external debt is left out of the regression) correlated with growth. They also find that once a measure for natural resource abundance is included in the regression, the importance and significance of the education variables decreases. Gylfason et al. give two possible explanations: If indeed a large primary sector prevents a “secondary” learning by doing generating sector, there is only little need for human capital, and education has no impact on growth. Moreover, if education is initially

poor, no “secondary” sector will emerge, and only the primary sector remains.

As a second test of the role of natural resource abundance in growth, Gylfason et al. use *the share of primary exports in total export* in 1970. The matching regressions indicate that this measure of natural resource abundance too is significantly negatively correlated with economic growth. Like the primary labor share measure, once introduced into the regression, the education variables lose their significance.

Gylfason et al. do not include a proxy for institutional quality in their regression. One could speculate, therefore, that a reason why they find that a large primary sector is negatively related to growth, is that a large primary sector is a sign of underdevelopment of other sectors, which have been relatively more damaged by poor institutions than the primary sector. Moreover, a common remark applies to both of the models of Dutch disease presented above. Both assume that growth purely takes its rise in a traded sector. Later (theoretical) work, e.g., Torvik (2001), argues that there may be reason to think that also the non-traded sector generates learning by doing. In this case, the hypothesis is that long-run growth is unaffected by altered resource abundance. As demonstrated in Frederiksen (2007), however, this result is vulnerable to issues of endogenous labor supply.

3.2 Institutions, Conflicts, and Social Infrastructure

A large share of the general resource curse literature is related to issues of political economy. Natural resources are, for instance, linked to political instability (Collier and Hoeffler 2004; Ross 2001, 2004) and ineffective governance (Tornell and Lane 1999; Robinson and Torvik 2004).

3.2.1 Leite and Weidmann (1999)

Leite and Weidmann (1999) examine if “mother nature corrupts.” First, they present a formal neoclassical growth model in which firms must bribe the government in order to be able produce. This model demonstrates that the optimal level of corruption increases with capital intensity in production, but at a decreasing rate, and that a higher level of corruption leads to slower growth towards the steady state.

Interpreting increased natural resource abundance as a positive technology shock, the net effect from increased natural resource intensity depends on the trade-off between the positive productivity shock and higher levels of corruption. Moreover, countries which have higher initial capital levels are marginally less harmed by an increase in corruption.

In testing these predictions, Leite and Weidmann account for endogeneity of corruption by estimating a two equation system. First, they estimate the effect of natural resource abundance on corruption, and, second, the effect of corruption and a direct effect from natural resources on growth. Arguing that different natural resources industries may have different effects on corruption and growth, for instance because they differ in capital intensity, natural resources are divided into *fuel and ores-* and *agriculture and food exports as a share of GDP* in 1970 after it has been tested that the coefficients of the two types of resources within each group are not significantly different in the “corruption regression.” Fuel and ores have a significant negative impact on corruption (increases corruption), whereas agriculture and food have significant positive effect. In the “growth regression,” low levels of corruption are significantly positively correlated with growth.

In addition to via corruption, natural resources are also directly included in the growth regression. When measured by *SXP* in 1970 they remain negatively associated with growth as in Sachs and Warner (1995). Decomposing *SXP* into separate types of natural resources in the growth regression reveals, that the only significant resource is food, which is negatively correlated with growth. Why only food impacts growth remains an open question left for future research.

3.2.2 Sala-i-Martin and Subramanian (2003)

While Sala-i-Martin and Subramanian (2003) pay special attention to the case of Nigeria, they also examine the resource curse hypothesis for a larger sample of countries. Inspired in part by the work of Hall and Jones (1999) and Acemoglu et al. (2001), they reconsider the idea, which is empirically rejected in Sachs and Warner (1995), that somehow natural resource abundance has an adverse effect on

institutions, and in this way (also) indirectly hinders growth.

As their measure of natural resource abundance they use both *SXP* in 1970 and 1980, as well as four other measures: the share of the exports in fuel, ores and metal, agricultural raw materials, and food in GDP and in total exports; the share of the exports of all natural resources in total exports; and a dummy for oil producing countries. To address the problem of potential endogeneity, they use initial values of the natural resource measure as independent variables in 1970 and 1980 respectively.

Treating natural resources as *undifferentiated* (*SXP*), and controlling for institutions using instruments such the fraction of the population which speaks English and European languages, they find no evidence that natural resource abundance is directly negatively correlated with economic growth. The sign of the coefficients of the two natural resource variables change over the two periods, and the variables, besides, are insignificant. Instead, a significant negative relationship between *SXP* and the rule of law suggests an indirect negative effect from natural resources onto institutional quality, which does not show up in the growth regressions once institutions are controlled for.

Among the *differentiated* natural resource types, agricultural and food generally have no influence on either growth or institutions. Minerals and fuel, on the other hand, are negatively correlated with both growth and institutions. Indeed, even after introducing regional dummies, mineral and fuel remain significantly negatively correlated with institutional quality. The oil dummy is positively correlated with growth, and negatively correlated with institutions, but the robustness of this finding not tested by regional dummies.

Sala-i-Martin and Subramanian (2003) perform a range of further tests. In particular, they find that the growth impact from mineral abundance is non-linear: “oil corrupts and excess oil corrupts more than excessively,” and their results are robust to choices of different control variables and measures of institutional quality.

3.2.3 Olsson (2003)

Olsson (2003) pays special attention to one particular point resource: diamonds. Olsson (*ibid.*, 2) argues that diamonds play a special role as targets for conflicts due to “their extremely high price, their efficient convertibility to money or arms, their small practical size, their indestructibility, and the difficulty with which their origin can be established.”

He presents a predator-prey model, in which there is a battle over a resource. On one side, the “ruler” seeks to defend the resource so its rents can be used on “public utilities,” and on the other hand a “rebel” seeks to control the resource to the “rebel’s” own benefit. When natural resource abundance is not high enough, the “ruler’s” defense expenses crowd out “public utilities” and growth declines as the resource gets more abundant. At a certain level, however, higher resource abundance increases income of the “ruler” enough that the “ruler” can spend more on “public utilities,” which in turn leads to an increase in growth. This trade-off predicts a U-shaped relationship between growth and natural resource abundance.

In his empirical test, Olsson uses three different measures of diamond abundance: *the value of diamond production as a share of GDP in 1999*,¹² *averaged annual production (1990-99) per sq km*, and *the value of production (in 2000) per sq km*. Olsson argues that the advantage of the latter is that they are not related to GDP, and the diamond measure is thus more likely to be exogenous.¹³ His empirical results indicate a convex relationship between diamond abundance and growth; i.e., countries with only little diamonds are cursed, and countries (Botswana) rich in diamonds are blessed. This relationship holds for all different diamond abundance specifications.

One apparent problem with Olsson’s test is that the results seem to be vulnerable with respect to the sample size. Once Botswana is excluded, the U-shape no longer

¹²The value of the production of diamonds is based on prices in 2000 and production quantity in 1999.

¹³Olsson (2003) argues that these two measures are “truly exogenous.” One may argue, however, that production could be endogenous in that richer countries are likely to have put more effort into locating diamond reserves.

holds. Instead, a linear negative relationship between diamonds prevails. In this case, his results are back in the Sachs and Warner (1995) framework, arguing a direct negative relationship between diamond abundance and economic growth.

3.2.4 Murshed (2004)

Also Murshed (2004) have point resources under suspicion. He considers rent seeking a likely explanation that this type of natural resources damages growth, and presents a neoclassical growth model, in which rent seeking activity, “contest,” damages capital productivity. Rent seeking activity is likely to be higher, the higher the value of the resources, i.e., higher for point resources than for diffuse resources. His hypothesis is that democracies decrease the success rate in rent seeking.

In a two equation estimation, he first estimates the effect of point and diffuse resources on democracy, and then the effect of democracy on growth, so that democracy is endogenously determined by the natural resources. As his measure of natural resources he uses a *dummy coded 1 for point resources*, if a country’s major export is a point resource, and likewise a *dummy coded 1 for diffuse resources* if a country’s major export is diffuse resources. Murshed finds that both types of resources have a negative impact on the level of democracy; however, only point resources significantly. Democracy, in turn, has a positive significant effect on growth. Thus, the findings of Murshed seem to confirm the results of Leite and Weidmann (1999) and Sala-i-Martin and Subramanian (2003), although he does not include natural resources directly in the growth regression.

3.2.5 Isham, Woolcock, Pritchett, and Busby (2005)

Also Isham et al. (2005) join this group. Their idea is that point resource abundance weakens institutions, which impairs their ability to respond effectively to shocks. As this ability is positively linked to higher growth, poor institutions may lead to slow growth rates.

Isham et al. distinguish between natural resources on the basis of *point*, *diffuse*, as well as *coffee and cocoa* resources. Resource abundance is measured by exports,

and in the growth regression, they use an index which refers to the degree of reliance of a particular resource in the exports earnings. In addition, they consider *SXP* in 1970. Using a two equation system, in which the first equation estimates the institutional quality based on natural resource abundance, and the second equation uses these institutional variables to estimate growth, Isham et al. find that particularly point source resources damage institutional quality, coffee and cocoa to a lesser extent, and diffuse resources have no significant effect. Institutional quality, in turn, is positively correlated to economic growth.

The impact of primary products export is less clear. *SXP* seems to have a positive effect on institutions, but a negative coefficient in the growth regressions, albeit not significant. Isham et al. (2005, 161) describe this result as: “a bit more speculatively, the hypothesis cannot be rejected that the only impact of export structure on growth is through institutions.” Isham et al. do not include the other natural resource variables directly in the growth regression, and whether natural resources have an effect on growth beyond that of through institutions, which Sala-i-Martin and Subramanian (2003) argue is not the case, is not examined.

3.2.6 Perälä (2003)

Perälä (2003) tests if slow growth in resource rich economies can be explained by lack of social cohesion,¹⁴ which, in turn, is adversely influenced by natural resources. In particular, she examines whether it makes a difference if a country is endowed with *diffuse* or *point* resources.

A country is classified as natural resource rich if per capita cropland is above 0.3 ha. Resource rich nations are further divided into point source economies if more than 40 percent of the total exports can be related to fuel and minerals.¹⁵ Resource rich countries not categorized as “point source” economies are defined as “diffuse source” economies and the remaining countries as resource poor countries.

¹⁴Social cohesion is measured by an ethnolinguistic fractionalization index taken from Easterly and Levine (1997).

¹⁵One may argue that it is not entirely obvious why a point source economy must have per capita cropland above 0.3 ha.

In the growth regressions, both types of natural resources have a negative impact on growth, but point resources reduce growth about twice the amount of diffuse resources. Both types of resources lose their significance once regional dummy variables and a lack of social cohesions in point resource economy variable are introduced. The lack of social cohesion in point resource economics variable is an interaction term between point resources and lack of social cohesions. Whereas the lack of social cohesion is insignificant, the interaction term is both significant and negative.

When instead a lack of social cohesion in diffuse resource economies variable is used in the growth regression, both diffuse and point resources continue to have significant negative relationships with growth, and the lack of social cohesion in diffuse economics variable is positively correlated to growth. No explanation for this puzzling relationship is offered, and once regional dummies are introduced, all natural resource measures, including the interaction term, lose their significance. Moreover, the lack of social cohesion in diffuse economies variable is not robust to various specifications of the controls. Accordingly, Perälä (2003) concludes that there is no evidence of any particular relationship between growth and diffuse resources.

This seems to suggest that resource abundance per se does not impede growth, but resource abundance of point resources in a fractionalized society does. As a robustness check, the social fractionalization of point resources variable is included in a number of well-known regressions, among them Sachs and Warner (1997).¹⁶ It turns out to be significant and increases the explanatory power of all regressions. In the Sachs and Warner specification, however, also SXP remains significant; high primary export shares are still negatively related to growth.

¹⁶The others are: Barro (1991), Mankiw et al. (1992), King and Levine (1993), and DeLong and Summers (1991).

3.2.7 Mehlum, Moene, and Torvik (2006)

Mehlum et al. (2006) present a theoretical model in which they distinguish between “grabber-friendly” and “producer-friendly” institutions that conditions a “grabber-equilibrium” or a “producer-equilibrium” respectively. In this model, natural resources are a curse in the “grabber-equilibrium”; while in a “producer-equilibrium” they are a blessing.

Mehlum et al. use *SXP* in 1970 to measure natural resource abundance. To test their hypothesis, they include in addition an interaction term between natural resources and institutional quality in the growth regression. Resource abundance is significantly negative, institutions are insignificant, and the interaction term is significant and positive. Hence, natural resources are damaging for growth only when institutions are weak. Changing the natural resource abundance measure to *the share of mineral production in GDP* in 1971, they find an even more negative impact on growth from the resource, and an even stronger positive effect on growth from institutional quality. In order to test the robustness of their results, they also control for education, ethnic fractionalization, and test if leaving out Africa has an effect. In all cases, resource abundance appears to harm growth, but good institutions can reverse the effect.

3.2.8 Boschini, Pettersson, and Roine (2005)

Boschini et al. (2005) perform a similar empirical test. In addition to the *SXP* measure, they introduce three other measures, which they argue are increasingly prone to appropriability, and hence, damage growth increasingly more: *the ratio of ores and minerals exports to GDP*, *the share of mineral production in GDP*, and *the share of gold, silver and diamonds in GDP*. Their empirical test confirms the results of Pärälä (2003) and Mehlum et al. (2006): natural resources, in particular minerals, are negatively correlated to growth, but the interaction term between the resources and institutional quality is positive. Moreover, their results confirm that gold, silver, and diamonds have the most negative impact on growth, followed by

ores and minerals exports and mineral production, and that *SXP* has the least negative impact on growth.

3.2.9 Ng (2006)

Ng (2006) argues that absolute natural resource abundance is likely to play a different role in explaining growth than relative natural resource abundance since the latter is likely to be “endogenous responses of production and trade.” Therefore, he distinguishes sharply between the two measures. The first, he argues, refers to exogenous endowments. For this variable he uses three measures: *the stock value of natural capital* in 1994, *the export value of natural resources* in 1970 and *the value-added component of GDP in natural resource sectors* in 1970. As a measure of relative natural resource abundance, he uses the *share of exports of natural resource goods in GDP* in 1970. All measures are divided into mineral and agricultural resources.

Controlling for investments and institutional quality, he finds that neither absolute abundance of minerals nor of agricultural resources have any significant impact on growth (nor on non-mining GDP growth). Relative mineral abundance, in turn, has a significant negative relationship to growth (and to non-mining GDP growth), whereas relative agricultural resource abundance has no significant impact.¹⁷ Ng proceeds to propose a neoclassical many-country two sector growth model with a mining and a non-mining sector and only TFP growth in the non-mining sector. By calibrating this model, he finds that its predictions confirm his empirical results.

Finally, he examines the empirical relationship between mineral resources and institutional quality. He finds that institutional quality is positively correlated with absolute mineral abundance, but negatively correlated with relative mineral abundance. Moreover, he finds that institutional quality is positively correlated with non-mining TFP; hence, countries with better institutions seem to have both

¹⁷Ng (2006) also examines output level effects, and find that mineral abundance has a significant positive impact on output levels, mineral dependence has no impact on output level, and neither agricultural abundance, nor agricultural dependence, exhibit any significant impact on output levels.

higher TFP levels and higher absolute mineral abundance.

Thus, Ng (2006) offers a new perspective on the resource curse: High absolute natural resource abundance does not harm growth per se; in fact, high absolute mineral abundance appears to have a positive impact on institutional quality. High relative natural resource abundance, on the other hand, possibly stems from low growth.

Summing this section on institutional pathways up, we find that there are two types of empirical results among the studies which consider a relative natural resource abundance measure: (1) Natural resources, especially, point resources damage institutional quality, which in turn damages growth (Leite and Weidmann 1999; Sala-i-Martin and Subramanian 2003; Murshed 2004; and Isham et al. 2005); and (2) natural resources have a negative impact on growth unless institutional quality is good, in which case, natural resources can be a blessing (Pärälä 2003; Mehlum et al. 2006; Boschini et al. 2005). Ng (2006), on the other hand, who uses a measure of absolute natural resource abundance find different results. He finds that point resources have a positive impact on institutional quality.

3.3 Other Pathways

3.3.1 Gylfason (2001)

Another concern, addressed by Gylfason (2001), is whether natural resource abundance has an adverse effect on human capital accumulation, and thereby also on economic growth. The idea is that resource rich nations may think, that natural resources is, and will remain, their main source of income, and therefore “inadvertently” fail to develop their human capital.

To test this idea, he uses the *share of natural capital in national wealth* in 1994 as measure of natural resource abundance. A two equation system estimates first the natural resource and school enrolment rate effects on growth controlling for initial income and investments; and second, the natural resource effect on enrolment rate controlling also for initial income. Gylfason finds a significant negative correlation both between natural resources and growth, as well as between natural resources

and enrolment rates, whereas enrolment rates and economic growth is positively correlated.

Considering the empirical results surveyed above, one explanatory variable in Gylfason's regression seems missing: some proxy for institutional quality. One may speculate that also poor institutions lead to low levels of enrolment rates. Moreover, if indeed, natural resources have an adverse effect on the quality of institutions; this would offer another explanation as to why natural resources seem to be negatively correlated with enrolment rates.

3.3.2 Manzano and Rigobon (2001)

The study of Manzano and Rigobon (2001) serves to purposes: First, it tests if the resource curse in Sachs and Warner (1995) is robust to panel estimation, and, second, it provides a new explanation for a negative relationship between natural resources and economic growth. As their measure of natural resource abundance, they use *SXP* in 1970 as well as *agricultural* and *non-agricultural export shares*. Non-agricultural export is further divided into minerals and fuel export shares. A resource curse shows up in their cross sectional estimations, but, when primary exports are decomposed, only non-agricultural resources are significant in explaining growth. Fuels are only slightly significant, whereas minerals have twice the impact on growth than that of fuels and are strongly significant. In contrast, Manzano and Rigobon find that a resource curse outcome is not robust to panel estimation, and suggest that a possible explanation is omitted variables.

After demonstrating that introducing institutional quality has no effect on the significant negative correlation between natural resources and growth, Manzano and Rigobon proceed to test their hypothesis: that the omitted variable may be initial debt to GNP ratio. They argue that resource rich countries were tempted to use natural resources as collateral when resource prices were high in the 70s, and, subsequently, were hit by "debt overhang" when prices fell in the 80s. Empirical analysis confirms their hypothesis: after controlling for "debt constraints," the natural resource variable is insignificant, and its coefficient is reduced substantially.

While being very careful in examining the effect of different types of natural resources on growth, a similar analysis is not provided for the effect of different types of natural resources on debt. An explanation could be that their hypothesis seems most relevant for non-agricultural resource rich countries.

3.3.3 Atkinson and Hamilton (2003)

A different, but also financial, perspective is taken by Atkinson and Hamilton (2003). Their concern is that natural resource rich countries subjugate to poor saving policies, i.e., low genuine saving rates, which, in turn, has adverse effects on growth. As their measure of natural resource abundance, they use *the average share of total resource rents in GDP over the period 1980-95*. Resource rents are calculated as the sum of rents from oil, gas, coal, basuxite, copper, iron, lead, nickel, phosphate, tin, zinc, gold, silver, and timber.

Estimating growth, using regional dummies, and controlling for initial income, investments, and human capital, they find that natural resource abundance is negatively correlated with growth. In order to explore if the presence of high resource rents has an adverse influence on government expenditure, they examine the interaction between government investment, government consumption, and the share of public sector wages in total government expenditure. It appears that the resource curse is present when governments spend resource rents to finance government consumption, and can be avoided when governments spend resource rents on investments. In the latter regression, natural resources have a significant negative impact on growth, but the interaction term between natural resources and government investments is positive and also significant. Hence, countries with higher government investments benefit from higher growth. Further analysis reveals that countries suffering from a resource curse are countries with a negative genuine saving.

A proxy for institutional quality is not included in the controls. It seems plausible, however, that poor institutions would amplify any tendency a government has to “liquidate,” rather than “create national wealth.” If natural resource abundance and poor institutional quality are correlated, the question is whether natural resources

remain significant after controlling for institutional quality.

3.3.4 Papyrakis and Gerlagh (2004)

Instead of focusing on one particular pathway, Papyrakis and Gerlagh (2004) examine a range of pathways: corruption, investments, openness, terms of trade, and schooling. To motivate these choices, they estimate the effect of natural resources on growth first without including these variables and then when including them. In the first case, natural resources, measured as *share of mineral production in GDP* in 1971, has a significant and negative impact on growth. After controlling for corruption, investments, openness, terms of trade, and schooling, natural resources lose their significance in explaining growth. Papyrakis and Gerlagh suggest therefore, that natural resources have no impact on growth per se, but instead they exercise their harm on growth indirectly.

The empirical analysis confirms that indeed natural resources are correlated with those variables. Natural resource abundance decreases openness, schooling, and investments, and increases corruption and terms of trade; although only significantly with respect to openness and terms of trade. Papyrakis and Gerlagh argue that this is due to the small sample size (39 countries) and that running each pathway separately, whereby a larger sample can be used, implies significance for all pathways, except corruption. In this way, Papyrakis and Gerlagh (2004) seem to confirm the findings of Gylfason (2001) on education and of Atkinson and Hamilton (2003) on saving. Natural resources may be a blessing, “if negative indirect effects are excluded.” Their results, however, disagree with Leite and Weidmann (1999) on the significance of a corruption transmission channel.

3.3.5 Stijns (2005)

A somewhat different approach is taken by Stijns (2005). Stijns decomposes natural resources into individual resources such as oil, gas, coal, minerals and land, and measures natural resource abundance by *reserves per 1000 capita* in 1999 and *land area per capita* in 1971. First, he examines the link between his reserve measures

and *SXP*, and finds that land has a significant positive effect on *SXP*. Moreover, it seems that coal has a negative effect on *SXP*, which he suggests is due to high transportations costs or that coal abundance is associated with secondary, instead of primary, exports.

Turning to the growth regressions, and using reserves as measure of natural resource abundance in the regression otherwise identical to that of Sachs and Warner (1995), Stijns finds no significant negative correlation between growth and natural resource reserves but land. While gas is negatively associated with growth, this effect is not significant, and coal has a positive, but also insignificant, effect. The effect and the sign of minerals and oil vary with the estimation specification, and neither is significant.

In the further analysis, Stijns reintroduces the *SXP* measure in the regression. *SXP* remains significant and negative even after controlling for natural resource reserves. Also land remains negative and significant whereas the other natural resource reserve measures are insignificant. Stijns provides a preliminary explanation to these results. He argues that perhaps land is associated with agricultural production which, in turn, may be oppositely related to growth.

The lack of significance of the resource reserves is the subject of further investigation, and Stijns suggests that these resources may influence economic growth through positive and negative channels which cancel out. He identifies five channels: political infrastructure, market orientation, savings and investment, human capital, and Dutch disease. Simple analysis of correlation (i.e., no controls) suggests that oil and gas have a positive effect on education, investment, and economic policy, but a negative effect on Dutch disease. Coal and minerals seem in particular to have a positive effect on economic policy and investment, whereas land is negatively correlated with all channels of influence.

Hence, Stijns (2005) seems to confirm the interpretation that natural resources are not a curse per se. Despite controlling for reserves and land, however, primary products export shares maintain their direct adverse effect on growth. Stijns concludes: “what matters most is what countries do with their natural resources.”

3.4 No Pathways

3.4.1 Sala-i-Martin, Doppelhofer, and Miller (2004)

As the last study in our survey, we include Sala-i-Martin et al. (2004). They perform a test of determinants of long-term growth using Bayesian model averaging. They do not explain channels of impact, but purely focus on identifying “robustness of explanatory variables in cross-country economic growth regressions.” As a measure of natural resource abundance they use two measures: *the fraction of GDP in mining in current prices* in 1994 as well as an *oil-producing country dummy*. The former belongs to the list of robust variables contributing positively to growth,¹⁸ whereas the latter is not significant.

4 Stylized Results

This section proceeds to synthesize the empirical findings of the 17 studies surveyed above and present them in a manner which we refer to as stylized results. Naturally, these stylized results are a rough presentation, but they serve a useful purpose as an overview and as a mean to answer our questions.

Table A2 in the appendix provides a full list of the different natural resource types considered by each study. In this table, we label each natural resource type as *non-differentiated*, *diffuse*, or *point* according to their appropriability. Following Boschini et al. (2005, fig. 1), diffuse resources are agricultural products; fish; meat; and fertile land. Point resources are diamonds; precious metals; oil and other minerals; coffee; cocoa; sugar; and timber. If both types of resources are considered jointly, the resource is labeled as non-differentiated.

In addition, table A4 in the appendix presents a list of the resource impact reported by the 17 studies. We distinguish between two types of resource impacts: *direct* and *indirect*. For studies, in which the main result is a direct effect, such as Sachs and Warner (1995, 1997), the indirect impact does not apply. Most studies,

¹⁸The authors, however, argue that this may be due to an outlier: Botswana. Botswana has benefited tremendously from its diamond industry.

however, examine pathways which relate natural resources abundance to growth performance. These studies can broadly be divided into two groups: studies that use a two equation system and studies that use an interaction term. For the first group, the direct effect is the effect from the resource *in excess* of their effect on the transmission channel. Some studies do not report this effect, e.g., Isham et al. (2005), whereas others do, e.g., Sala-i-Martin and Subramanian (2003). The sign of the indirect impact is the effect that natural resources have on growth via the transmission channel.

For the other group, the group of studies which use an interaction term, the direct effect is the effect natural resources have on growth, once an interaction term is introduced in the regression. The indirect effect, in this case, indicates the sign of the interaction term. The interpretation of a positive interaction term is that natural resource is a blessing for growth once the interaction effect exceeds any direct negative effect.

4.1 Stylized Result 1: Natural Resource Type Matters

Table 2 presents natural resource impact by natural resource type: *non-differentiated*, *diffuse*, and *point*, based on table A2 and A4 in the appendix.

Natural Resource Type	Direct Impact				Indirect Impact ^a			
	Obs	Neg.	ns ^b	Pos.	Obs	Neg.	ns	Pos.
Non-differentiated (N)	10	7	3	0	3	2	0	1
Diffuse (D)	10	2	8	0	5	1	3	1
Point (P)	22	6	14	2	13	9	1	3
Total	42	15	25	2	21	12	4	5

^aExcluding studies which use an interaction term.

^bns: non-significant; include also U-shape and situations where no clear effect is reported (indicated by “?” in table A4).

Examining the patterns in table 2, it seems that natural resources mostly have been found to have no, or a negative, direct impact on growth and a negative impact via their transmission channel. As the full effect on growth of a given natural resource is the sum of the indirect effect and any remaining direct effect,

table 2 suggests that all three groups of natural resource types typically have been shown to a negative effect on growth. Point resources more than diffuse resources, but the studies which investigate *non-differentiated* natural resources seem to have the highest incidence of a natural resource curse. An ad hoc ranking according to the incidence of a natural resource curse implies that:

non-differentiated resources > point resources > diffuse resources.

This ranking seems peculiar: As non-differentiated resources generally are the sum of both point and diffuse resources, one would expect that non-differentiated resources would be no worse than point resources. A possible explanation of why this reasoning does not correspond to the pattern in table 2, upon which the ranking is based, is suggested by our next stylized result.

4.2 Stylized Result 2: Natural Resource Measurement Matters

In providing this result, we draw on table A3 and table A4 in the appendix. Table A3 assign labels to each study according to whether it uses a relative or an absolute natural resource abundance measure.

Table 3 Natural Resource Measure Classification and Sign of the Resource Impact

Natural Resource Measure	Direct Impact				Indirect Impact ^a			
	Obs	Neg.	ns ^b	Pos.	Obs	Neg.	ns	Pos.
Relative abundance (R)	32	14	16	2	16	11	3	2
Absolute abundance (A)	10	1	9	0	5	1	1	3
Total	42	15	25	2	21	12	4	5

^aExcluding studies which use an interaction term.

^bns: non-significant, include also U-shape and situations where no clear effect is reported (indicated by “?” in table A4).

Examining the patterns in table 3, it seems that using a relative measure gives much worse results in term of a more frequent natural resource curse than using an absolute measure:

relative abundance > absolute abundance.

Moreover, it seems that there is no systematic pattern in how natural resources measured by their absolute abundance impacts growth: the evidence of a positive effect and of a negative effect appears roughly equal. Separating by natural resource type (cf. table A4 in the appendix), it appears that absolute land abundance has a negative indirect impact on growth, whereas absolute point resource abundance has no or a positive indirect impact on growth. This result is, however, based only on two studies: Stijns (2005) and Ng (2006).

Moreover, caution must be taken in drawing firm conclusions from the ranking given under *stylized result 1* and *stylized result 2*. Precisely the natural resource type *non-differentiated* and the *relative natural resource abundance measure* are used by Sachs and Warner (1995, 1997). Many of the empirical analyses are, to a greater or lesser extent, based on the dataset of Sachs and Warner (1995, 1997). It is therefore possible, that an issue that has to do with selection of dataset is also contributing the results.¹⁹

4.3 Stylized Result 3: Natural Resources Impact Growth for a Variety of Reasons

To examine the pathways through which natural resource abundance and growth is related, we distinguish between studies which have explored the natural resource curse by use of a transmission channel and by use of an interaction term.

According to table 4 below, which is based on table A3 and table A4 in the appendix, it seems that *diffuse* resources have a missing, or a positive, relationship with institutional quality. Only Stijns (2005) finds that a *diffuse* resource, land per capita, is bad for economic performance by indirect transmission channels. *Point* resources, in turn, seem to have many pathways through which they can harm growth: debt overhang, less openness, worse terms of trade, more corruption, less democracy, and poorer institutions. The results of Ng (2006), however, stand out in that they suggest that point resources have a positive impact on institutional

¹⁹For instance, Lederman and Maloney (2002), among other things, find that Sachs and Warner's (1995) results are not robust with respect to changes in time horizon.

quality when measured by their absolute abundance.

All studies which use an interaction term find a non-negative coefficient on the interaction term, which suggests that when the level of institutional quality is high enough, natural resources are a blessing for economic growth.

Table 4 Transmission Channels, Interaction Term, and Indirect Resource Impact by Natural Resource Type and Measure

Transmission channel	Indirect Resource Impact		
	Neg.	ns ^a	Pos.
Debt (Manzano and Rigobon)	P/R		
Education (Gylfason)	N/R		
Five channels (Stijns)	D/A	P/A	
Openness and ToT (Papyrakis and Gerlagh)	P/R		
Institutions:			
Corruption (Leite and Weidmann)	P/R		D/R
Democracy (Murshed)	P/R	D/R	
Institutions (Sala-i-Martin and Subramanian)	N/R; P/R	D/R	
Institutions (Isham et al.)	P/R; P/R	D/R	N/R
Institutions (Ng)	P/R		P/A; P/A; P/A
Interaction term			
Gov. expenditure (Atkinson and Hamilton)			P/R
Institutions (Boschini et al.)			P/R; P/R; P/R; P/R
Institutions (Mehlum et al.)			P/R; P/R
Lack of social cohesion (Perälä)		D/n.a.	P/n.a.

Note: N: non-differentiated resources; P: point resources; and D: diffuse resources; A: absolute natural resource abundance; R: relative natural resource abundance.

^ans: non-significant, include also situations where no clear effect is reported (indicated by “?” in table A4).

5 Additional Data

The aim of this section is to provide some additional data to the survey. In particular, we consider the relationship between growth performance and the share of value added by natural resource industries relative to GDP. Among the studies included in the survey, also Sala-i-Martin et al. (2004) consider this measure of natural resource abundance. They, however, consider only the mining industry; here, in addition, we include also agricultural industries in the analysis.

We use a simple cross sectional growth regression that describes economic growth in country i between time $t = 0$ and $t = T$. Growth is a function of initial GDP, Y_0^i , and a vector of structural characteristics X^i :

$$\frac{\ln(Y_T^i/Y_0^i)}{T} = \alpha_0 + \alpha_1 \ln(Y_0^i) + \alpha_2 X^i + \varepsilon^i. \quad (1)$$

A negative sign of α_1 can be interpreted as a conformation of the conditional convergence hypothesis: across countries, ceteris paribus, high income countries grow more slowly than low income countries. We are especially interested in examining if natural resources are among the X^i 's. Based on our general survey results, we expect a negative coefficient on natural resources which can be defined as point resources, whereas we expect the coefficient on diffuse natural resources to be insignificant.

In addition, we perform an analysis in which we include an interaction term between natural resources and institutional quality among the X^i 's. According to our survey, we expect the coefficient on this interaction term to be positive for point resources and insignificant for diffuse resources.

5.1 Sample and Data Sources

For our measure of natural resource abundance, we use data sources from the United Nations National Account Statistics (SNA 2006). Our data cover the period 1991-2003. National account estimates are prepared once a year for all countries and break real GDP down by industries. This feature allows us to distinguish two main natural resource industries: “agriculture, hunting, forestry, and fishing”; and “mining and quarrying.”²⁰ “Agriculture, hunting, forestry, and fishing” can be further subdivided into *agriculture, hunting, and forestry* and *fishing* as separate industries.²¹

²⁰Mining and quarrying includes extraction of crude petroleum and natural gas as well as service related activities.

²¹Actually, data can be even further divided into agriculture, hunting, and related service activities and forestry, logging, and related service activities. Future research could try to disentangle agriculture and forestry.

For the empirical analysis we use a measure of relative resource abundance. Specifically, we use the share of value added by natural resource industries relative to GDP in 1996.²² Not every national account includes all four natural resource industries. We therefore create four samples. Each sample is constructed on the basis of one of four natural resource variables: *Min*; *AgrForFish*; *AgrFor*; and *Fish*. Tables A7 to A10 present the full lists of countries within each sample.

As our dependent variable we use average growth over the period 1991-2003 (calculated as $(\ln Y_{2003}^i - \ln Y_{1991}^i) * 100/12$), and as our measure of income, we use real GDP per capita (chain), both of which are taken from Penn World Table 6.2.²³ For our other explanatory variables we use investment share of real GDP in 1991 ($(I/Y)_{1991}$) which is also taken from Penn World Table 6.2, and a proxy for institutional quality, the rule of law in 1996, which is taken from Kaufmann et al. (2006).²⁴ The rule of law measure ranges from -2.5 to 2.5, where a higher score means better rule of law. The rule of law indicates the “extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, the police, and the courts, as well as the likelihood of crime and violence” (ibid., 4). Table A5 in the appendix contains a detailed specification of all variables and Table A6 in the appendix lists their mean and standard deviation.

5.2 Results

Table 5 shows the cross sectional growth regressions of each sample corresponding to (1) using simple ordinary least squares (OLS). We perform an analysis with and without the interaction term.

As expected, the coefficient on initial income is negative, and, in addition, significant. The coefficient implies a rate of conditional convergence between roughly a half and one percent per year. Institutions are significant and positively correlated

²²We choose 1996 because from this year on, more and more countries differentiate agriculture, forestry and fishing into separate industries. Ideally, we would have liked to use year 1991.

²³http://pwt.econ.upenn.edu/php_site/pwt_index.php.

²⁴<http://info.worldbank.org/governance/kkz2005/pdf/2005kkdata.xls>.

with growth, whereas the interaction term is not significant in any sample (as can be seen in OLS1b, OLS2b, OLS3b, OLS4b). Common to all regressions is that they have low levels of explanatory power, and lower than most of the studies reviewed in the literature above.

The first regression, OLS1a, examines the relationship between *Min* and growth, controlling for initial income, initial investment share, and the rule of law. The coefficient on *Min* is negative, but not significant. This result seems to contradict most evidence presented in the survey above, which finds a negative relationship between point resources and growth performance. Sala-i-Martin et al. (2004), however, find that the size of the mining industry relative to GDP is positively correlated with growth.

Table 5 Growth Regressions

Dependent variable: Average GDP per capita growth 1991-2003								
Sample	Min		AgrForFish		AgrFor		Fish	
	OLS1a	OLS1b	OLS2a	OLS2b	OLS3a	OLS3b	OLS4a	OLS4b
Constant	6.30*** (2.86)	6.46*** (2.94)	11.88*** (3.88)	12.55*** (3.90)	10.93*** (3.90)	11.34*** (4.00)	7.01** (2.55)	7.26** (2.62)
lnY ₁₉₉₁	-0.59** (-2.23)	-0.61** (-2.29)	-1.15*** (-3.49)	-1.22*** (-3.53)	-1.09*** (-3.53)	-1.14*** (-3.64)	-0.73** (-2.28)	-0.75** (-2.34)
(I/Y) ₁₉₉₁	0.03 (1.41)	0.03 (1.44)	0.03* (1.84)	0.03* (1.77)	0.04** (2.23)	0.04** (2.26)	0.05*** (2.66)	0.06*** (2.69)
Rule of Law	0.69** (2.27)	0.59* (1.86)	0.57** (2.33)	0.68** (2.33)	0.62** (2.35)	0.75** (2.55)	0.66** (2.14)	0.72** (2.27)
Resources ¹	-0.01 (-0.86)	-0.03 (-1.38)	-0.07*** (-2.92)	-0.08*** (-2.88)	-0.07** (-2.51)	-0.08*** (-2.70)	-0.03 (-0.20)	-0.16 (-0.79)
Interaction ²		0.03 (1.29)		-0.01 (-0.69)		-0.02 (-1.00)		-0.18 (-0.87)
R ² adjusted	0.07	0.08	0.13	0.12	0.17	0.17	0.13	0.13
N	106	106	112	112	82	82	68	68

Notes: The *t*-statistic for the coefficients is in the parentheses.

*10% level of significance, **5% level of significance, ***1% level of significance.

¹The resource variable considered is: Min; AgrForFish; AgrFor; and Fish respectively.

²The interaction term is the interaction between the resource and the rule of law variable.

The OLS2a regression analyses the relationship between the relative size of all agricultural industries to GDP and growth. The coefficient on *AgrForFish* is both negative and significant. A 10 percent increase in the share of all agricultural

industries in GDP decreases average growth performance by 0.7 percentage points. A similar pattern is repeated in OLS3a in which the fishing industry is excluded from the resource variable.

A hypothesis, which could explain why a the relative size of the agricultural industry is negatively correlated with growth, is that a relatively large agricultural industry may be a sign of general underdevelopment of other, more productive, sectors; an indication that the economy has not yet entered an “industrial” or “new-economy” stage. Indeed, Quella (2006) find that labor-generated knowledge spillovers and TFP growth in agricultural sectors in the US economy are small compared to other sectors of the US economy. Within the group of OECD countries, however, OECD (2003) finds that agricultural TFP growth has outperformed TFP growth in other sectors in 1970-1990.

The picture changes when considering the correlation between the size of the fishing industry relative to GDP and growth, which is done in OLS4a. The coefficient on the fishing industry is not significant. One could speculate that a reason why the fishing industry seems to have a different impact on growth than the agricultural industry is that countries with a large fishing industry also have easy access to the sea. They are therefore less likely to be landlocked. Malik and Temple (2006) argue that geography and, in particular, landlockness, increases output volatility, and others, e.g., Ramey and Ramey (1995), have argued that high output volatility is negative correlated with growth performance.

Summing up, for reasons yet to be solved,²⁵ our regression analyses seem to produce results counter to the general “stylized results” of studies which also use a relative natural resource abundance measure presented above. One may argue, that this divergence emphasizes that there is still much to be understood in how natural resources interact with growth performance. We stress, however, that our empirical analysis only offers preliminary results.

²⁵The analysis can, for instance, be extended by use of regional dummies.

6 Concluding Remarks

We conclude that the story of the resource curse appears to be a complex story. The type of natural resources matters, how they are measured matters, and there is a range of pathways through which natural resources impact growth.

Specifically, among the 17 studies chosen for our survey, more studies show evidence that *point* resources are negatively correlated with growth than evidence that *diffuse* resources are negatively correlated with growth. Almost all studies that examine *non-differentiated* resources, i.e., all primary products, find a negative relationship between growth and natural resource abundance.

An important factor in these results, however, seems to be how natural resource abundance is measured. Measured in relative terms, such as relative to the overall size of the economy, natural resources seem consistently negatively correlated with growth performance. This type of measure is used by the majority of studies in our survey. In sharp contrast to this result, is the seemingly lack of empirical evidence to support that absolute levels of natural resources damage growth.

Transmission channels are numerous, but no general pattern seems to emerge. Point resources appear to cast their curse through weakened human capital accumulation, damaged institutional quality, increased debt, and worse terms of trade, but, at the same time there is also evidence that point resources bless growth through better institutional quality. Also diffuse resources are found to both harm and benefit institutional quality. Indeed, examining this issue of endogenous institutional quality further is possible subject for future research: What are the trade-offs which determine whether natural resources benefit or harm institutions?

Our empirical cross sectional analysis suggests that the size of the combined agricultural and forestry industry relative to GDP is negatively correlated with growth, whereas neither the size of the mining industry nor of the fishing industry relative to GDP seems to have any systematic relationship with growth. We argue, that these findings, albeit preliminary, confirm that a general pattern in how various types of natural resources impact growth is not easily established. Hence,

we conclude that there is still much to be understood in whether natural resources take one route or the other to impact growth.²⁶ In addition, the present paper takes the rather simple approach of purely considering the *sign* of the resource impact. Future work might compare the *magnitude* of the natural resource impact across different studies.

It seems also that an important issue remains unsolved: Can we be sure that is it the natural resources that matters? If indeed high relative natural resource abundance is a proxy for underdevelopment, the resource curse should be interpreted as a symptom of underdevelopment rather than an indication of a negative impact from natural resources onto growth. One may argue we still lack reliable estimates and that the question of causality remains open. A potential solution to the problem would be to find an instrument variable for natural resources. In this respect, absolute abundance measures seem superior. For instance, site quality may be a valid instrument of land's yielding capacity, and thus agricultural abundance.

Another subject for further elaboration is that of linking the resource curse to issues of global development and environmental issues. Chichilnisky (1994) argues that poorly defined property rights on natural resources in resource rich poor countries lead to over-extraction (via trade) of the natural resource and hence a deterioration of the global environment.

²⁶This is the topic of the two subsequent chapters of this thesis (Frederiksen 2006, 2007).

A Appendix

Table A1 Chronological Presentation of Studies and Some Statistics

Study	ID	Sample Size	Growth Period
Sachs and Warner 1997 ^b	1	87-71	1970-90
Gylfason, Herbertsson, and Zoega 1999	2	125-65	1960-92
Leite and Weidmann 1999	3	72	1970-90
Gylfason 2001	4	85	1965-98
Manzano and Rigobon 2001	5	74-54	1970-90
Atkinson and Hamilton 2003	6	91	1980-95
Olsson 2003	7	124-123 ^b	1990-99
Perälä 2003	8	82-79	1960-99
Sala-i-Martin and Subramanian 2003	9	70-69	1970-98
Murshed 2004	10	50	1970-2000
Papyrakis and Gerlagh 2004	11	103-39	1975-96
Sala-i-Martin, Doppelhofer, and Miller 2004	12	88	1960-96
Isham et al. 2005	13	66-22	1974-97
Boschini, Pettersson, and Roine 2005	14	80	1975-98
Stijns 2005	15	87-71	1970-89
Mehlum, Moene, and Torvik. 2006	16	87-59	1965-90
Ng 2006	17	70	1970-2000

^aWe list Sachs and Warner (1997) as this study considers an additional year.

^bOut of which 18 countries produce diamonds.

Table A2 Natural Resource Types and Type Classification

ID	*	Natural Resource Type (NR)	Type Classification		
			Non-differentiated (N)	Diffuse (D)	Point (P)
1		Primary products	N		
2	a	Labor force in primary sector	N		
	b	Primary products	N		
3	a	Agriculture and food		D	
	b	Fuels and ores			P
4		Natural wealth	N		
5	a	Primary products	N		
	b	Agricultural products		D	
	c	Non-agricultural products			P
6		Oil, minerals, et al., and timber			P
7		Diamonds			P
8	a	Diffuse		D	
	b	Point			P
9	a	Primary products	A		
	b	Agricultural products		D	
	c	Non-agricultural products			P
	d	Oil producer			P
10	a	Diffuse		D	
	b	Point			P
11		Minerals			P
12	a	Mining			P
	b	Oil producer			P
13	a	Diffuse		D	
	b	Point			P
	c	Coffee and cocoa			P
	d	Primary products	A		
14	a	Primary products	A		
	b	Ores and metals			P
	c	Minerals			P
	d	Gold, silver, diamonds			P
15	a	Land		D	
	b	Oil, coal, minerals, gas ^a			P
	c	Primary products	N		
16	a	Primary products	N		
	b	Minerals			P
17	a	Agricultural products		D	
	b	Minerals			P

See Appendix A1 for list of sources

^aStijns (2005) considers these natural resources separately, but only land plays a separate role.

Table A3 Natural Resource Measures and Measure Classification

ID*	Natural Resource Measure	Measure Classification	
		Relative(R)	Absolute(A)
1	$\left(\frac{\text{NR export}}{\text{GNP}}\right)_{1970} \equiv \text{SXP}_{1970}$	R	
2a	$\left(\frac{\text{NR}}{\text{All labor}}\right)_{1965}$	R	
2b	$\left(\frac{\text{NR export}}{\text{All export}}\right)_{1970}$	R	
3a,b	SXP_{1970}	R	
4	$\left(\frac{\text{NR wealth}}{\text{National wealth}}\right)_{1994}$	R	
5a,b,c	SXP_{1970}	R	
6	$\left(\frac{\text{NR rents}}{\text{GDP}}\right)_{1980-95}$	R	
7	$\left(\frac{\text{Value of NR production}}{\text{GNP}}\right)_{2000}$	R	
7	$\left(\frac{\text{NR production}}{\text{Country size}}\right)_{1990-99}$		A
7	$\left(\frac{\text{NR value}}{\text{Country size}}\right)_{2000}$		A
8a	1, if exp. include < 40% mineral and oil	n.a. ^a	
8b	1, if exp. include > 40% mineral and oil	n.a.	
9a,b,c	$\left(\frac{\text{NR export}}{\text{All export}}\right)_{1970,80}$	R	
9b,c	$\left(\frac{\text{NR export}}{\text{GDP}}\right)_{1970,80}$	R	
9d	1, if NR exp.: > $\frac{2}{3}$ all exp., and = 1% of world NR exp.	R	
10a,b	1, if NR is the major source of exp.	R	
11	$\left(\frac{\text{Value of NR production}}{\text{GDP}}\right)_{1971}$	R	
12a	$\left(\frac{\text{NR value added}}{\text{GDP}}\right)_{1994}$	R	
12b	1, if NR exp.: > $\frac{2}{3}$ all exp., and = 1% of world NR exp	R	
13a,b,c	$\left(\frac{\text{NR net export}}{\text{Net export}}\right)_{1980}$	R	
13d	SXP_{1970}	R	
14a	SXP_{1970}	R	
14b	$\left(\frac{\text{NR export}}{\text{GDP}}\right)_{1975}$	R	
14c	$\left(\frac{\text{Value of NR production}}{\text{GDP}}\right)_{1971}$	R	
14d	$\left(\frac{\text{Value of NR production}}{\text{GDP}}\right)_{1972-80}$	R	
15a	$\left(\frac{\text{NR}}{\text{Capita}}\right)_{1971}$		A
15b	$\left(\frac{1000 * \text{NR reserves}}{\text{Capita}}\right)_{1999}$		A
15c	SXP_{1970}	R	
16a	SXP_{1970}	R	
16b	$\left(\frac{\text{NR production}}{\text{GNP}}\right)_{1971}$	R	
17a,b	$\left(\frac{\text{NR stock value}}{\text{Worker}}\right)_{1994}$		A
17a,b	$\left(\frac{\text{NR export}}{\text{Worker}}\right)_{1970}$		A
17a,b	$\left(\frac{\text{NR value added}}{\text{Worker}}\right)_{1970}$		A
17a,b	$\left(\frac{\text{NR export}}{\text{GDP}}\right)_{1970}$	R	

See Table A1 for list of sources and Table A2 for NR specifications.

^aSince, in addition, cropland/capita > 0.3 ha in 1970

Table A4 Natural Resource Impact and their Transmission Channels/Interaction Term

ID*	Natural Resource Type (NR)	Resource Impact ^a		Channel/Interaction Term
		Direct	Indirect	
1	Primary product	-	...	...
2a	Labor force in primary sector	-	...	...
2b	Primary products	-	...	...
3a	Agriculture and food	ns and -	+	Corruption/
3b	Fuels and ores	ns and ns	-	Corruption/
4	Natural wealth	-	-	Education/
5a	Primary products	-	...	...
5b	Agricultural products	ns	...	...
5c	Non-agricultural products	ns	- ^b	Debt/
6	Oil, minerals, et al., and timber	-	+/-	/Government expenditure
7	Diamonds (R, A)	U-shape	...	...
8a	Diffuse	ns	?	/Lack of social cohesion
8b	Point	ns	-	/Lack of social cohesion
9a	Primary products	ns	-	Institutions/
9b	Agricultural products	ns	ns	Institutions/
9c	Non-agricultural products	ns	-	Institutions/
9d	Oil producer	+	-	Institutions/
10a	Diffuse	...	ns	Democracy/
10b	Point	...	-	Democracy/
11	Minerals	ns	-	Openness and terms of trade/
12a	Mining	+	...	...
12b	Oil producer	ns	...	...
13a	Diffuse	...	ns	Institutions/
13b	Point	...	-	Institutions/
13c	Coffee and cocoa	...	-	Institutions/
13d	Primary products	ns	+	Institutions/
14a	Primary products	ns	ns	/Institutions
14b	Ores and metals	-	+	/Institutions
14c	Mineral	-	+	/Institutions
14d	Gold, silver, diamonds	-	+	/Institutions
15a	Land	-	-	Five channels/
15b	Oil, coal, minerals, gas	ns	+/?	Five channels/
15c	Primary products	-	...	...
16a	Primary products	-	+	/Institutions
16b	Minerals	-	+	/Institutions
17a	Agricultural products (R, A)	ns	...	...
17b	Minerals (R)	-	-	Institutions/
17b	Minerals (A)	ns	+	Institutions/

See Table A1 for list of sources

^aNatural resource impact on growth. ns: non-significant (cf. level used by the source).

^bThe effect on non-agr. resources on debt is not tested directly

Table A5 List of Variables

Variable	
Growth	Average yearly growth rate (in percent). [$\ln(\text{rgdpch03}-\text{rgdpch91}) \cdot 100 / 13$]]. Source: PWT 6.2.
$\ln Y_{1991}$	Real GDP per capita in constant dollars (Chain). [$\ln(\text{rgdpch91})$]. Source: PWT 6.2.
$(I/Y)_{1991}$	Investment share of real GDP per capita (in percent). [KI1991] Source: PWT 6.2
Rule of Law	Score between -2.5 and 2.5. Taken from year 1996. Source: Kaufmann et al. (2006).
Min	Value added by Mining and Quarrying at constant prices in 1996 (in percent). Source: SNA (2006).
AgrForFish	Value added by Agriculture, Forestry, Hunting and Fishing at constant prices in 1996 (in percent). Source: SNA (2006).
AgrFor	Value added by Agriculture, Forestry and Hunting at constant prices in 1996 (in percent). Source: SNA (2006).
Fish	Value added by Fishing at constant prices in 1996 (in percent). Source: SNA (2006).

Table A6 Means and Standard Deviations of Variables for each Sample

Variable	Min		AgrForFish		AgrFor		Fish	
	Mean	σ	Mean	σ	Mean	σ	Mean	σ
Growth	1.76	1.61	1.69	1.60	1.63	1.54	1.72	1.48
$\ln Y_{1991}$	8.63	1.07	8.64	1.08	8.74	1.11	8.71	1.10
$(I/Y)_{1991}$	14.6	8.43	15.14	9.16	10.07	10.48	15.81	9.81
Rule of Law	0.26	0.97	0.25	0.98	0.34	1.03	0.33	1.00
Resource	5.27	9.09	13.64	12.28	10.07	10.48	0.98	1.66
Interaction	1.12	8.77	-4.79	14.44	-3.81	10.84	-0.37	1.53

Table A7 List of Countries in Min-sample

Albania	Ecuador	Mauritius	Senegal
Argentina	Egypt	Mexico	Slovak Republic
Australia	El Salvador	Mongolia	Slovenia
Austria	Estonia	Morocco	South Africa
Bahamas	Finland	Mozambique	Spain
Bahrain	France	Namibia	Sri Lanka
Bangladesh	Germany	Nepal	Suriname
Belgium	Ghana	Netherlands	Swaziland
Belize	Greece	New Zealand	Sweden
Benin	Guatemala	Nicaragua	Switzerland
Bhutan	Honduras	Niger	Syria
Bolivia	Hungary	Nigeria	Thailand
Botswana	Iceland	Norway	Tonga
Cambodia	India	Oman	Trinidad Tobago
Cameroon	Indonesia	Pakistan	Tunisia
Canada	Israel	Panama	Turkey
Cape Verde	Italy	Papua New Guinea	Uganda
Chile	Jamaica	Paraguay	United Kingdom
Colombia	Japan	Peru	United States
Costa Rica	Jordan	Philippines	Uruguay
Cote d'Ivoire	Kenya	Poland	Venezuela
Croatia	Korea, Republic of	Portugal	Vietnam
Cuba	Kuwait	Puerto Rico	Yemen
Cyprus	Laos	Qatar	Zambia
Czech Republic	Lesotho	Romania	Zimbabwe
Denmark	Luxembourg	Rwanda	
Dominican Republic	Malaysia	Saudi Arabia	

Table A8 List of Countries in AgrForFish-sample

Albania	Dominican Republic	Malawi	Rwanda
Argentina	Ecuador	Malaysia	Saudi Arabia
Australia	Egypt	Mauritius	Senegal
Austria	El Salvador	Mexico	Singapore
Bahamas	Estonia	Mongolia	Slovak Republic
Bahrain	Finland	Morocco	Slovenia
Bangladesh	France	Mozambique	South Africa
Belgium	Germany	Namibia	Spain
Belize	Ghana	Nepal	Sri Lanka
Benin	Greece	Netherlands	Suriname
Bhutan	Guatemala	New Zealand	Swaziland
Bolivia	Honduras	Nicaragua	Sweden
Botswana	Hungary	Niger	Switzerland
Brunei	Iceland	Nigeria	Syria
Cambodia	India	Norway	Thailand
Cameroon	Indonesia	Oman	Tonga Tobago
Canada	Iran	Pakistan	Trinidad
Cape Verde	Israel	Panama	Tunisia
Chad	Italy	Papua New Guinea	Turkey
Chile	Jamaica	Paraguay	United Kingdom
Colombia	Japan	Peru	United States
Costa Rica	Jordan	Philippines	Uruguay
Cote d'Ivoire	Kenya	Poland	Uzbekistan
Croatia	Korea, Republic of	Portugal	Venezuela
Cuba	Kuwait	Puerto Rico	Vietnam
Cyprus	Laos	Qatar	Yemen
Czech Republic	Lesotho	Romania	Zambia
Denmark	Luxembourg	Russia	Zimbabwe

Table A9 List of Countries in AgrFor-sample

Argentina	Czech Republic	Kuwait	Russia
Australia	Denmark	Lesotho	Rwanda
Austria	Ecuador	Luxembourg	Senegal
Bahamas	El Salvador	Malaysia	Slovak Republic
Bahrain	Estonia	Mexico	Slovenia
Bangladesh	Finland	Mongolia	Spain
Belgium	France	Mozambique	Suriname
Bhutan	Germany	Namibia	Swaziland
Bolivia	Ghana	Netherlands	Sweden
Botswana	Greece	New Zealand	Switzerland
Brunei	Honduras	Nicaragua	Thailand
Cambodia	Hungary	Nigeria	United Kingdom
Cameroon	Iceland	Norway	United States
Canada	India	Oman	Uruguay
Cape Verde	Indonesia	Panama	Uzbekistan
Chad	Iran	Peru	Venezuela
Chile	Italy	Philippines	Vietnam
Colombia	Jamaica	Poland	Yemen
Cote d'Ivoire	Japan	Portugal	Zambia
Croatia	Kenya	Romania	Zimbabwe
Cyprus	Korea, Republic of		

Table A10 List of Countries in Fish-sample

Argentina	Cyprus	Jamaica	Philippines
Austria	Czech Republic	Japan	Poland
Bahamas	Denmark	Kenya	Portugal
Bahrain	Ecuador	Korea, Republic of	Romania
Bangladesh	El Salvador	Kuwait	Rwanda
Belgium	Estonia	Lesotho	Senegal
Botswana	Finland	Malaysia	Slovenia
Brunei	France	Mexico	Spain
Cambodia	Germany	Mozambique	Suriname
Cameroon	Ghana	Netherlands	Sweden
Canada	Greece	New Zealand	Thailand
Cape Verde	Honduras	Nicaragua	United Kingdom
Chad	Hungary	Nigeria	Uruguay
Chile	India	Norway	Venezuela
Colombia	Indonesia	Oman	Vietnam
Cote d'Ivoire	Iran	Panama	Yemen
Croatia	Italy	Peru	Zambia

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CHAPTER 3

Spending Natural Resource Revenues in an Altruistic Growth Model

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Abstract

This paper examines how revenues from a natural resource interact with growth and welfare in an overlapping generations model with altruism. The revenues are allocated between public productive services and direct transfers to members of society by spending policies. We analyze how these policies influence the dynamics, and how the dynamics are influenced by the abundance of the revenue. Abundant revenues may harm growth, but growth and welfare can be oppositely affected. We also provide the socially optimal policy. Overall, the analysis suggests that variation in the strength of altruism and in spending policies may be part of the reason why natural resources seem to affect economic performance across nations differently.

Key Words: Natural Resources, Economic Growth, Welfare, Altruism

JEL Classification Codes: D64, O41, Q33, Q38

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1 Introduction

The aim of this paper is to propose an endogenous growth model in which the relationship between growth performance and natural resource abundance can be studied. Especially, we explore the hypothesis that the political economy and the strength of altruism matters for how natural resource abundance affects growth.

The idea of a resource curse¹ is not new; it dates back in history. The decline of Spain's prosperity after its colonization of the New World and discovery of large amounts of gold and other precious metals is a classical example. Also within recent decades, has the idea of a resource curse received support by a large body of empirical (see Auty 1993, 2001; Sachs and Warner 1995, 1999, 2001, among others) as well as theoretical literature.² Classical theories include the Dutch disease theory (Corden and Neary 1982; Torvik 2001; van Wijnbergen 1984), rent seeking problems (Tornell and Lane 1999; Torvik 2002), and political economy explanations (Ross 2004, 2006; Robinson and Torvik 2005). Rodriguez and Sachs (1999) suggest that natural resource rich countries are overshooting their consumption levels and consequently converge to their steady states from above, which results in slow rates of economic growth.

Empirical evidence, however, which questions an unconditional negative relationship between natural resources and growth, seems also to be emerging (Sala-i-Martin et al. 2004; Stijns 2005; Frederiksen 2007; Ng 2006). Besides, a classical counterexample to the resource curse is oil-rich Norway. Larsen (2005) concludes that resources are a blessing for Norway's economy.³

Yet only a limited number of theoretical studies have tried to explain a diverging experience of the resource impact on economic performance. Exception includes Mehlum et al. (2006). They argue that growth performance varies with

¹We use the term "resource curse" to describe the situation in which resource abundant nations grow slower than nations endowed with fewer resources. In the literature, the term is sometimes used in a more general way to describe poor economic performance. For our analysis, however, it is important to distinguish between growth and welfare effects.

²For a recent survey of the theoretical literature, consult Stevens (2003).

³He notes, however, a slow-down in growth after the mid-90s.

how resource revenues are distributed between “grabbing” and production, which, in turn, depends on the type of institution. The paper empirically supports that the resource curse is weaker, or completely missing, in countries with producer friendly institutional quality. In general, however, while there has been intense focus on analyzing natural resources in positive settings, an important aspect, how best to manage the resource revenues despite potential harmful growth effects, has been largely ignored.⁴

Revenues from natural resources are typically managed by governments, and political economic factors are likely to influence how revenues are spent. Spending policies, in turn, possibly matters for how revenues impact economic performance. The political economy literature often argues that abundant natural resources lead to poor spending policies. The idea is that “easy” revenues corrupt, bring about conflicts (Ross 2004, 2006), and encourage economically inefficient - but politically important - projects (Robinson and Torvik 2005). To mitigate such problems, Sala-i-Martin and Subramanian (2003) suggest, at least for the case of Nigeria, to decentralize revenues by distributing them directly to the people by which the government is forced to finance public services by taxes. Taxes may be costly to collect, yet overall society gains in that collecting taxes is claimed to incorporate a disciplining mechanism which protects against wasteful projects.⁵

We argue that nations may be in different stages of economic development, or what we refer to as different economic growth regimes, and that across such stages, economic factors as private savings differ in the way they are generated. Insofar that savings matter for growth, decentralized revenues may therefore have different impacts on economic development.

⁴One exception is Matsen and Torvik (2005). They analyze an optimal intertemporal consumption path in a Dutch disease model, and show that the growth maximizing policy differs from the welfare maximizing policy. In their framework, this means some Dutch disease is optimal. Within the literature of exhaustible natural resources, the literature of how optimally to manage resource revenues in order to achieve intergenerational equity is well established, see, e.g., Hartwick (1977) and Solow (1974, 1986).

⁵A similar proposal is made by Sandbu (2006). He argues that tax revenues differ from resource revenues in that the first is considered as out-of-pocket losses and the latter as forgone gains by members of society. In general, he argues, members of society are more likely to hold the government accountable for out-of-pocket losses than for forgone rents.

We model the possibility of different growth regimes, and the possibility of different spending policies in a unified framework. We use a two-period overlapping generations growth model in which individuals are altruistic in that parents care about the welfare of their children. Parents have the possibility to leave bequests, which they will do, when their altruism is sufficiently high. In this case, the economy is dynastic and behaves like an infinitely-lived representative agent model, whereas the economy behaves like an overlapping generations model, when altruism is not intense enough and bequests are absent (Barro 1974; Weil 1987). Resource revenues enter the model in every period as a fixed fraction of man-made output. They are allocated according to a spending policy as direct transfers to members of society and as expenditures on a public productive service as in Barro (1990).

Our results suggest a potential caveat to decentralizing resource revenues. While trying to avoid a resource curse created through political economy mechanisms by distributing revenues directly to members of society, a resource curse may be created due to economic factors instead. In addition, we examine various endogenous spending policies and find that under such policies, increased resource abundance may lead to a shift in growth regime to a regime with a lower growth rate; as such a shift implies higher welfare.

Our model is related to that of Papyrakis and Gerlagh (2004), but more general. Papyrakis and Gerlagh (2004) study a two-generation overlapping generations model (without altruism), in which resource revenues are given entirely to the retired old generation. Higher revenues means less savings, and therefore the economy is resource cursed.⁶ Our study emphasizes that the resource curse is fragile with respect to variation in the allocation of revenue across generations, and that potential adverse effects on savings can be remedied by spending policies that stimulate intergenerational transfers.

Our model is also related to the literature that studies effectiveness of economic

⁶The authors consider in an appendix a situation, in which all individuals (i.e., young and old) equally divide the resource revenue and find that resource revenues are less harmful to savings than when revenues are only given to the old.

policy in an altruistic setting. Caballe (1998) analyzes how taxation of labor and capital influences not only growth performance, but also the growth regime. In his model, the level of altruism that distinguishes the growth regimes is determined by the tax policy. Croix and Michel (2002, ch. 5) analyze the neutrality of economic policy, when the bequest motive is operative.

The paper proceeds as follows. We present the model in section 2. In section 3, we explain the market equilibrium and characterize the conditions for the altruism factor which distinguishes the growth regimes. In section 4, we examine different policy objectives, derive corresponding spending policies, and analyze the impact of natural resource revenues on growth and welfare under these policies. In section 5, we study the optimal policy, and the final section provides concluding remarks.

2 The Model

The economy is closed and described by a one sided altruistic overlapping generations' framework. Parents care about the welfare of their offspring and have the possibility to make intergenerational transfers to their immediate descendants in the form of bequests. Individuals live for two periods: as young and as old. Only the young generation works, the old generation is retired. There are L individuals in each generation, which remains constant over time.

2.1 Natural Resource Revenues

In every period t , revenues from the sale of a natural resource enter the economy. The value of the revenue is exogenously given as a fixed fraction, ξ , of the real value of man-made output, Y_t , where $0 < \xi < 1$. We may think of ξ , which we refer to as relative natural resource abundance, as a characteristic that is country specific.⁷

⁷Natural resource revenues vary considerably across countries. For instance, Iceland, Nigeria, Norway and Venezuela have a share of primary exports in GDP above 0.2, whereas Nepal, Sweden and the US have a share of primary exports below 0.1. (<http://www.cid.harvard.edu/ciddata/ciddata.html>.)

Let E_t denote the real value of the revenue; then,

$$E_t = \xi Y_t. \quad (1)$$

Accordingly, our theoretical model applies also to inflows of foreign aid and other gifts and transfers from “abroad.” As the resource revenue man-made output ratio is constant over time, we focus purely on spending policies in relation to intergenerational transfers and economic growth.⁸ Similar ways of modeling of the revenue (or foreign aid) are found in Chatterjee et al. (2003), Lensink and White (2001), Papyrakis and Gerlagh (2004), and Torvik (2001).⁹

2.2 Spending Policies

Based on a spending policy, a government spends all resource revenues in every period on one or two purposes.

First, it may allocate a share, τ , where $0 \leq \tau < 1$, directly to members of society in a lump-sum fashion.¹⁰ Of this share, the young share parameter, π , is given to the young generation and $(\tau - \pi)$ to the old; i.e., $0 \leq \pi \leq \tau$.

Second, the government invests the remaining resource revenue in a public service flow, G_t , that works as input into production. We think of the public service as a broad range of services that could be infrastructure, administration, legal, and environmental services. There are no externalities associated with the use of public services.

In every period, the government runs a balanced budget. It cannot issue debts nor run surpluses by accumulating assets. Hence,

$$G_t = (1 - \tau)E_t = (1 - \tau)\xi Y_t. \quad (2)$$

⁸For a reference on optimal resource extraction, consult Dasgupta and Heal (1979).

⁹Torvik (2001) discusses alternative ways of modeling the revenue in footnote 4, p. 290. The important assumption is that the revenue grows over time so that, as a share of income, it does not converge towards zero.

¹⁰A real example of direct transfers of resource rents is found in Alaska. One purpose of the so-called Alaska Permanent Fund is to distribute the returns of the fund, which come from minerals and oil, to all inhabitants of the state in the form of a check (Hannesson 2001).

Therefore, the resource constraint, which is the public budget, satisfies

$$\pi E_t + (\tau - \pi)E_t + (1 - \tau)E_t = E_t = \xi Y_t. \quad (3)$$

2.3 Firms

A representative firm produces man-made output, Y_t , and uses three factors in production: labor, L , the average public service flow per worker, $g_t \equiv G_t/L$, and capital, K_t . Output per worker, y_t , is produced according to the following production technology:

$$y_t = A g_t^\alpha k_t^{1-\alpha}, \quad (4)$$

where $0 < \alpha < 1$ is the share of labor and of public services in production, A is a positive constant productivity term, and k_t is capital per worker. Labor productivity increases as the public service flow per worker, g_t , increases.¹¹

The representative firm maximizes profits taking g_t , as well as the price of output, which is the *numeraire*, and of inputs, as given. Capital fully depreciates in each period, and each factor is paid its private marginal product.

$$\frac{\partial Y_t}{\partial K_t} = (1 - \alpha)A \left(\frac{g_t L}{K_t} \right)^\alpha = 1 + r_t, \quad (5)$$

$$\frac{\partial Y_t}{\partial L_t} = \alpha A \left(\frac{g_t L}{K_t} \right)^\alpha k_t = w_t. \quad (6)$$

where r_t is the rental rate of capital, and w_t is the wage rate.

2.4 Altruistic Individuals

Newborn individuals are identical within as well as across generations. A parent is altruistic with respect to the welfare of her offspring in the Barro (1974) sense and weights her offspring's utility in her utility function, V_t . Let U_t denote utility derived from life-cycle consumption; thus, total utility of an individual at time t can be presented as

$$V_t = U_t + \beta V_{t+1}, \quad (7)$$

¹¹The public service flow per worker is non-rival, but subject to congestion from L .

where $0 < \beta < 1$ is the intergenerational discount factor, which we refer to as the altruism factor. When generations are altruistic, parents care about the welfare of their children, who in turn care about the welfare of their children, and so forth. In this way, welfare of all future generations is linked.

Utility from own consumption is the sum of utility from consumption as young, c_{1t} , and the discounted utility of consumption as old, c_{2t+1} . Specifically,

$$U_t = u(c_{1t}) + \rho u(c_{2t+1}) = \ln(c_{1t}) + \rho \ln(c_{2t+1}), \quad (8)$$

where $0 < \rho < 1$ is the intertemporal discount factor. By recursively eliminating V_{t+i} , $i = 0, \dots, \infty$, in (7) we have.¹²

$$V_t = \sum_{i=0}^{\infty} \beta^i [\ln(c_{1t+i}) + \rho \ln(c_{2t+1+i})], \quad (9)$$

saying that utility of a young individual born at time t equals own life-cycle utility plus the discounted sum of life-cycle utilities of her descendants.

In any period t , the young individual inelastically supplies one unit of labor for which she receives the market wage rate, w_t . When the young share parameter, π , is positive, she also receives a direct transfer as a share of the natural resource revenue, and, finally, she may inherit bequests, b_t , from her parents. She consumes c_{1t} and saves s_t for her retirement; hence,

$$c_{1t} + s_t = b_t + w_t + \pi e_t, \quad (10)$$

where $\pi e_t \equiv \pi E_t/L$ denotes the lump-sum resource revenue income of a young at time t . When old, she receives the proceeds of her saving, $(1 + r_{t+1})s_t$, where r_{t+1} is the rate of interest. In addition, if $\pi < \tau$, she receives income from the natural resource, which she consumes and possibly bequeaths to her offspring. Accordingly, her period two budget constraint can be written as

$$c_{2t+1} + b_{t+1} = (1 + r_{t+1})s_t + (\tau - \pi)e_{t+1}, \quad (11)$$

¹²Eq. (7) can be rewritten by induction as $V_t = \sum_{i=0}^T \beta^i [u(c_{1t+i}) + \rho u(c_{2t+1+i})] + \beta^{T+1} V_{t+1+T}$. Taking the limit for $T \rightarrow \infty$ and assuming that total utility satisfy the limit condition $\lim_{T \rightarrow \infty} \beta^{T+1} V_{t+1+T} = 0$, we get $V_t = \sum_{i=0}^{\infty} \beta^i [u(c_{1t+i}) + \rho u(c_{2t+1+i})]$. Using $U_t = \ln(c_{1t}) + \rho \ln(c_{2t+1})$, we have (9).

where $(\tau - \pi)e_{t+1}$ is the resource revenue given lump-sum to an old person at time $t + 1$. Bequests cannot be negative, i.e., $b_{t+1} \geq 0$. This restriction prevents parents from leaving debts to their children.

The dynamics of bequests are found by eliminating s_t in (10) and (11):

$$b_{t+1} = (1 + r_{t+1})(b_t + w_t + \pi e_t - c_{1t}) + (\tau - \pi)e_{t+1} - c_{2t+1}. \quad (12)$$

An individual of generation t maximizes life time utility given in (9) subject to the two budget constraints, (10) and (11), and the non-negativity constraint on bequests, by optimally choosing consumption, savings, and bequests, taking b_t , w_t , r_{t+1} , e_t , and e_{t+1} as given.

The Lagrangian of period t is equal to life-cycle utility, U_t , with the change $\beta p_{t+1}b_{t+1} - p_t b_t$ in the shadow value of bequests, p_t , over a period (Croix and Michel 2002, 244)

$$\mathcal{L}_t = \ln(c_{1t}) + \rho \ln(c_{2t+1}) + \beta p_{t+1}b_{t+1} - p_t b_t. \quad (13)$$

Note that $b_{t+1} \geq 0$ implies $(1 + r_{t+1})(b_t + w_t + \pi e_t) + (\tau - \pi)e_{t+1} \geq (1 + r_{t+1})c_{1t} + c_{2t+1}$. Incorporating this restriction in the maximization problem, the optimality conditions, which are both necessary and sufficient, are given by

$$\frac{1}{c_{1t}} = \frac{\rho(1 + r_{t+1})}{c_{2t+1}}, \quad (14)$$

and

$$b_{t+1} \left(\frac{\beta}{c_{1t+1}} - \frac{\rho}{c_{2t+1}} \right) = 0 \quad (\text{with } b_{t+1} \geq 0 \text{ and } \frac{\beta}{c_{1t+1}} \leq \frac{\rho}{c_{2t+1}}). \quad (15)$$

The transversality condition is

$$\lim_{t \rightarrow \infty} \beta^t p_t b_t = 0. \quad (16)$$

Equation (14) describes the trade-off between a person's consumption as young and as old. In optimum, the individual is indifferent between consuming as young and saving for old consumption. In equation (15), when $\frac{\beta}{c_{1t+1}} = \frac{\rho}{c_{2t+1}}$ then $b_{t+1} > 0$ and when $\frac{\beta}{c_{1t+1}} < \frac{\rho}{c_{2t+1}}$ then $b_{t+1} = 0$. When bequests are positive, a parent's marginal utility of own consumption equals her marginal utility of the offspring's

consumption. If a parent's marginal utility from her offspring's consumption is less than the marginal utility of her own consumption, then bequests are zero, and the solution is given by a corner solution.

3 Competitive Equilibrium

For simplicity, we normalize the number of working people, L , to unity, so we can write $E_t = e_t$, $Y_t = y_t$, $K_t = k_t$, and $G_t = g_t$. We obtain the following expression by rewriting (4) using (2):

$$y_t = Ak_t \left[\frac{(1-\tau)\xi y_t}{k_t} \right]^\alpha \Leftrightarrow y_t = [A(1-\tau)^\alpha \xi^\alpha]^\frac{1}{1-\alpha} k_t \equiv f(\tau, \xi)k_t \quad (17)$$

where $\frac{\partial f(\tau, \xi)}{\partial \tau} < 0$. The larger the share of the natural resource revenues spent on direct transfers, the smaller the public service flow. This implies a smaller public service flow capital ratio, $\frac{g_t}{k_t}$. Due to the AK structure of the model, it also leads to a drop in the output capital ratio. Therefore, all things equal, $\frac{\partial f(\tau, \xi)}{\partial \xi} > 0$; higher revenues increase public services.

Using (4), factor market clearing implies

$$r_t = (1-\alpha)A\left(\frac{g_t}{k_t}\right)^\alpha - 1, \quad (18)$$

$$w_t = \alpha A\left(\frac{g_t}{k_t}\right)^\alpha k_t, \quad (19)$$

and using (17) in (18) and (19), we get

$$r_t = (1-\alpha)f(\tau, \xi, \cdot) - 1 \equiv r(\tau, \xi), \quad (20)$$

$$w_t = \alpha f(\tau, \xi, \cdot)k_t \equiv w(\tau, \xi)k_t, \quad (21)$$

where $w(\tau, \xi)$ denotes the wage rate capital ratio. Both the rate of return and the wage rate are positively associated with the public service flow capital ratio, $\frac{g_t}{k_t}$, and, thus, $\frac{\partial r(\tau, \xi)}{\partial \tau} < 0$ and $\frac{\partial w(\tau, \xi)}{\partial \tau} < 0$.

The capital market equilibrium requires savings of the young to equal capital installed in the productive sector:

$$s_t = k_{t+1}. \quad (22)$$

Lastly, the goods market equilibrium is given by the aggregate resource constraint. Using the budget constraints (10), and (11), and the equilibrium conditions (2), (20), (21), and (22), the aggregate resource constraint can be expressed as

$$(1 + \xi)y_t = c_{1t} + c_{2t} + k_{t+1} + g_t. \quad (23)$$

Total income in period t is the sum of man-made output plus the natural resource revenue.

3.1 Dynamics

In the following, we distinguish two growth regimes of the economy based on the presence of intergenerational transfers. When parents marginal utility of own consumption is larger than the marginal utility they derive from the offspring's consumption, the non-negativity constraint on bequests is binding, and there are no bequests.

3.1.1 Zero Bequests

Assume that (15) holds with inequality so bequests are absent. Letting $b_t = b_{t+1} = 0$ in (10) and (11), we can, by also using (14), derive the an expression for the savings s_t :

$$s_t = \frac{\rho}{1 + \rho} [w(\tau, \xi)k_t + \pi e_t] - \frac{(\tau - \pi)e_{t+1}}{(1 + \rho)[1 + r(\tau, \xi)]}. \quad (24)$$

Savings are increasing in wages and resource revenues received as young and decreasing in resource revenues received as old. This is intuitive; consumption smoothing requires higher savings the smaller income is as old compared to income as young.

Using (22), we get from (24)

$$k_{t+1} = \frac{\rho}{1 + \rho} [w(\tau, \xi)k_t + \pi e_t] - \frac{(\tau - \pi)e_{t+1}}{(1 + \rho)[1 + r(\tau, \xi)]},$$

which is the law of motion of capital. Dividing both sides by k_t , we find

$$\gamma_{t+1}^O = \frac{\rho}{1 + \rho} [w(\tau, \xi) + \pi \frac{e_t}{k_t}] - \frac{(\tau - \pi) \frac{e_t}{k_t} (\gamma_{t+1}^O + 1)}{(1 + \rho)[1 + r(\tau, \xi)]} - 1,$$

where $\gamma_{t+1}^O = (k_{t+1}/k_t) - 1$ is the growth rate of capital (and also capital per worker due to a constant labor force) when bequests are absent. Note that $e_t = \xi y_t = \xi f(\tau, \xi, \cdot)k_t$. Rearrange, and γ_{t+1}^O can be expressed as

$$\gamma_{t+1}^O = \frac{\rho[1 + r(\tau, \xi)][w(\tau, \xi) + \pi \xi f(\tau, \xi)]}{(1 + \rho)[1 + r(\tau, \xi)] + (\tau - \pi)\xi f(\tau, \xi)} - 1 \equiv \gamma^O(\pi, \tau, \xi). \quad (25)$$

We define a balanced growth path as a path along which c_{1t} , c_{2t} , k_t , y_t , g_t , and e_t grow at constant relative rates in all periods $t > 0$. From (17) it follows that capital grows at the same rate as output. Since resource revenues are given as a fixed fraction of output (in (1)), it follows immediately that also revenues grow at the same rate as output. Moreover, as public services are given as a fixed fraction of total resource revenues (in (2)), public services grow at the same rate as output. From the goods market equilibrium, (23), it follows that aggregate consumption (c_{1t} plus c_{2t}) grows at the same rate of output. By (14), (20), and $r_t = r(\tau, \xi)$, it then follows that period one and period two consumption grow at the rate of output. Hence, the bequest constrained economy has no transitional economics; c_{1t} , c_{2t} , k_t , y_t , g_t , and e_t grow at the same rate along a balanced growth path at all periods t .

We denote values taken by the variables on the balanced growth path without bequests with the superscript “ O .” Using (20), (21), and taking $k_0^O > 0$ as given, equilibrium is given by

$$c_{1t}^O = f(\tau, \xi)(\alpha + \pi \xi) \frac{1 - \alpha + (\tau - \pi)\xi}{(1 + \rho)(1 - \alpha) + (\tau - \pi)\xi} k_t^O \equiv c_{1t}^O(\pi, \tau, \xi), \quad (26)$$

$$c_{2t}^O = f(\tau, \xi)[1 - \alpha + (\tau - \pi)\xi] k_t^O \equiv c_{2t}^O(\pi, \tau, \xi), \quad (27)$$

$$k_{t+1}^O = \frac{\rho(1 - \alpha)f(\tau, \xi)(\alpha + \pi \xi)}{(1 + \rho)(1 - \alpha) + (\tau - \pi)\xi} k_t^O \equiv k_{t+1}^O(\pi, \tau, \xi). \quad (28)$$

On this growth path, parents behave as if they are selfish as they do not leave intergenerational transfers. Essentially, the economy behaves like an overlapping generations model.

Growth is positive when income received in period one is sufficiently large to ensure that savings exceed the capital depreciation. Accordingly, $\rho(1 - \alpha)f(\tau, \xi)(\alpha + \pi \xi) > (1 + \rho)(1 - \alpha) + (\tau - \pi)\xi$ implies that $\gamma^O(\pi, \tau, \xi) > 0$.

3.1.2 Positive Bequests

When bequests are positive, by (15) $\frac{\beta}{c_{1t+1}} = \frac{\rho}{c_{2t+1}}$ and the economy is dynastic. In this regime, the growth rate of period one consumption, γ_{t+1}^D , is found by dividing the first order solutions given in (14) and (15):

$$\gamma_{t+1}^D = \beta[1 + r(\tau, \xi)] - 1 \equiv \gamma^D(\beta, \tau, \xi). \quad (29)$$

Again, we define a balanced growth path as a path along which c_{1t} , c_{2t} , k_t , y_t , g_t , b_t , and e_t grow at a constant relative rates in all periods $t > 0$. From (17) it follows that capital grows at the same rate as output. Since resource revenues are given as a fixed fraction of output (in (1)), it follows immediately that natural resource revenues grows at the same rate as output. Moreover, as public services are given as a fixed fraction of resource revenues (in (2)), also public services grow at the rate of output.

By the goods market equilibrium, (23), and $r_t = r(\tau, \xi)$, it must be that if capital and output grow as the same rate, then this rate equals that of growth of consumption. From (14), we know that consumption as old and as young is a constant ratio, so old consumption grows at the same rate as young consumption. From either of the budget constraints (10) or (11), it follows that also bequests grow at the same rate as consumption. Thus, also the bequest constrained economy has no transitional economics; c_{1t} , c_{2t} , k_t , y_t , g_t , b_t , and e_t grow at the same rate along a balanced growth path at all periods t .

From the first order conditions to (13), it can be shown that p_t equals $\frac{1}{c_{1t}}$, when bequests are positive.¹³ Hence, p_t decreases at the rate $\gamma^D(\tau, \xi)$. We can thus conclude, when $b_t > 0$, $p_t b_t$ is a constant, and the transversality condition in (16) simplifies to $\beta < 1$. When (15) holds with equality, parents leave bequests and the economy behaves like a dynasty of infinitely-lived generations.

We denote values taken by the variables on the balanced growth path with

¹³By (13), $\frac{\partial \mathcal{L}_t}{\partial c_{1t}} = 0$ implies that $\frac{1}{c_{1t}} = \beta p_{t+1}[1 + r(\tau, \xi)]$, and $\frac{\partial \mathcal{L}_t}{\partial b_t} = 0$ implies that $p_t = \beta p_{t+1}[1 + r(\tau, \xi)]$, so it follows that $\frac{1}{c_{1t}} = p_t$.

positive bequests with the superscript “ D .” Equilibrium is given by

$$b_t^D = f(\tau, \xi) \left\{ \frac{\beta\tau\xi - \rho + [\rho + \beta(1 + \rho)](1 - \alpha)}{\beta + \rho} - \pi\xi \right\} k_t^D \equiv b_t^D(\beta, \tau, \xi), \quad (30)$$

$$c_{1t}^D = \beta f(\tau, \xi) \left[\frac{1 + \tau\xi - \beta(1 - \alpha)}{\beta + \rho} \right] k_t^D \equiv c_{1t}^D(\beta, \tau, \xi), \quad (31)$$

$$c_{2t}^D = \rho f(\tau, \xi) \left[\frac{1 + \tau\xi - \beta(1 - \alpha)}{\beta + \rho} \right] k_t^D \equiv c_{2t}^D(\beta, \tau, \xi), \quad (32)$$

$$k_{t+1}^D = \beta f(\tau, \xi)(1 - \alpha)k_t^D \equiv k_{t+1}^D(\beta, \tau, \xi), \quad (33)$$

with $k_0^D > 0$.

Along this growth path, the growth rate is positive when $\beta > \frac{1}{1+r(\tau, \xi)}$. This condition says, for a young individual to have positive savings and bequests, marginal utility of consuming one unit extra as young is less than marginal utility derived from letting the offspring consume $1 + r(\tau, \xi)$ units.

Clearly, the growth paths described by (25) and (29) in general differ, as does the way they respond to changes in revenues and in spending policies.

3.2 The Resource Curse

The *resource curse* typically indicates a negative relationship between natural resource abundance and economic performance. In this paper, the resource curse specifically describes the situation where resource abundant nations grow slower than nations endowed with fewer resources. We can think of two possibilities of why an economy may be “resource cursed”: when spending policies are such that increased abundance (i) leads to savings decline, and (ii) leads to a regime shift to a regime with a lower growth rate. In the following, we explain and examine both possibilities.

3.2.1 Savings Decline

Indeed, we find that savings may be negatively influenced by increased resource revenues. In particular,

LEMMA 1. *Within growth regimes, there exist exogenous policies (τ, π) that imply a resource curse. When bequests are absent (whether this is due to the policy*

or a low altruism factor) increased natural resource abundance can lead to a lower growth rate.

PROOF. When bequests are absent, along $\gamma^O(\xi, \cdot)$:

$$\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} = \frac{\left\{ \frac{\partial f(\tau, \xi)}{\partial \xi} \rho(1 - \alpha)(\alpha + \pi \xi) + f(\tau, \xi) [\rho(1 - \alpha)\pi - \frac{\rho(1 - \alpha)(\alpha + \pi \xi)(\tau - \pi)}{(1 + \rho)(1 - \alpha) + (\tau - \pi)\xi}] \right\}}{(1 + \rho)(1 - \alpha) + (\tau - \pi)\xi}.$$

A policy where $\pi = 0$ and $\tau(1 - 2\alpha) > \frac{(1 - \alpha)\alpha}{\xi}(1 + \rho)$ implies $\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} < 0$. In a dynastic growth regime,

$$\frac{\partial \gamma^D(\xi, \cdot)}{\partial \xi} = \beta(1 - \alpha) \frac{\partial f(\tau, \xi)}{\partial \xi} > 0 \quad \forall 0 \leq \tau < 1$$

proves the non-existence of a resource curse, when bequests are positive. \square

An operative bequest motive eliminates the resource curse threat as the growth rate in this regime is increasing in the rate of return to capital, which, in turn, is increasing in resource abundance; i.e., $\frac{\partial r(\tau, \xi)}{\partial \xi} > 0$. Savings are unaffected by the allocation of direct transfers as any change in revenues given to a young individual is offset by an identical opposite change in bequests.¹⁴ Hence, the rate of growth in this environment, $\gamma^D(\beta, \tau, \xi)$, is independent of π .

When bequests are absent, accumulation of capital depends on the distribution of resource revenues across generations. For example, a policy that distributes all direct transfers solely to the old generation may lead to a resource curse outcome, in which, higher resource abundance results in fewer savings. The resource curse prevails when, due to increased resource abundance, a young individual derives higher marginal utility of consuming as young than as old; i.e., what generates the resource curse is a “disproportional” large direct transfer to the old generation in the situation where bequests are absent. Therefore,

PROPOSITION 1. *Given an exogenous policy (τ, π) , then when direct transfers*

¹⁴To see this notice that along a balanced growth path, eq. (12) can be rewritten as $b_t^D(\cdot) = \frac{(1+r(\cdot))(w(\cdot)k_t^D + \pi e_t^D - c_{1t}^D) + (\tau - \pi)(1 + \gamma^D(\cdot))e_t^D - \frac{\rho}{\beta}(1 + \gamma^D(\cdot))c_{1t}^D}{(1 + \gamma^D(\cdot)) - (1 + r(\cdot))}$, where $\frac{\partial b_t^D(\cdot)}{\partial \pi} = -e_t^D$. Now, write $s_t = \frac{\rho}{1 + \rho}(b_t^D + w(\cdot)k_t^D + \pi e_t^D) - \frac{(\tau - \pi)(1 + \gamma^D(\cdot))e_t^D - (1 + \gamma^D(\cdot))b_t^D}{(1 + \rho)(1 + r(\cdot))} \equiv s_t^D(\pi)$. Calculating $\frac{\partial s_t^D(\pi)}{\partial \pi}$ using $\frac{\partial b_t^D(\cdot)}{\partial \pi} = -e_t^D$ gives $\frac{\partial s_t^D(\pi)}{\partial \pi} = 0$.

from the government are absent, or when they, if present, are allocated only to the young generation, there is no resource curse.

PROOF. By lemma 1, we only analyze an economy without bequests.

If $\pi = \tau = 0$, then

$$\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} = \frac{\rho \alpha}{1 + \rho} \frac{\partial f(\tau, \xi)}{\partial \xi} > 0 \quad \forall \tau = 0,$$

and, if $\pi = \tau$, then

$$\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} = \frac{\rho}{1 + \rho} \left[\frac{\partial f(\tau, \xi)}{\partial \xi} (\alpha + \tau \xi) + f(\tau, \xi) \tau \right] > 0 \quad \forall 0 < \tau < 1. \quad \square$$

A larger inflow of revenues, *ceteris paribus*, enhances the public service flow capital ratio and, thus, the wage rate and the rate of return. When direct transfers are positive, young income increases further relative to old income and savings grow.

We make an interesting observation about the resource curse:

PROPOSITION 2. *Increased resource abundance may improve welfare of the two current generations, despite causing a resource curse.*

PROOF. See appendix.

Next, we turn to examine how it can be determined that a particular economy belongs to either of the two growth regimes and how the economy may shift between growth regimes. In particular, we focus on relating these issues to spending policies and to the size of the revenue to man-made output ratio, ξ .

3.2.2 Growth Regime Shifts

Though the altruism factor, β , is exogenously given, whether bequests are positive or zero, is determined endogenously by the first order condition given in (15). From (15), we know that when parents marginal utility of own consumption is greater than their marginal utility from the offspring's consumption, the economy is without bequests. A decline in the consumption of the offspring relative to consumption of the parent triggers intergenerational transfers, if the decline is large enough.

We define the threshold value of the altruism factor, β^* , such that under a given spending policy, (τ, π) , when $\beta = \beta^*$ then $\gamma^O(\pi, \tau, \xi) = \gamma^D(\beta, \tau, \xi)$. In the special case, where $\beta = \beta^*$, $b_t^D(\beta, \tau, \xi) = 0$ and parents leave zero bequests. Inverting (29), substituting in (25), using (20), and (21) yields

$$\beta^* = \frac{\rho(\alpha + \pi\xi)}{(1 + \rho)(1 - \alpha) + (\tau - \pi)\xi} \equiv \beta^*(\pi, \tau, \xi). \quad (34)$$

Using this definition of β^* , we obtain the standard result (Caballe 1998; Cardia and Michel 2004; Weil 1987) that, when the altruism factor is less than the threshold value, $\beta < \beta^*(\pi, \tau, \xi)$, the economy is without bequest, and the growth path is described by (25). On the other hand, when the altruism factor is higher than the threshold value, $\beta > \beta^*(\pi, \tau, \xi)$, bequests are positive, and growth evolves according to (29). We can now compare growth rates in the two regimes:

PROPOSITION 3. *Given $\beta \neq \beta^*$, then, if $\beta > \beta^*$, the economy grows faster than if $\beta < \beta^*$.*

PROOF. We note, by eq. (34), that eq. (25) can be rewritten as $\gamma^O(\pi, \tau, \xi) = \beta^*(\pi, \tau, \xi)(1 - a)f(\tau, \xi) - 1$. Since the economy follows this growth path as long as $\beta < \beta^*(\pi, \tau, \xi)$, but changes to $\gamma^D(\beta, \tau, \xi) = \beta(1 - a)f(\tau, \xi) - 1$ with positive bequests when $\beta > \beta^*(\pi, \tau, \xi)$, it must be that $\gamma^O(\pi, \tau, \xi, \cdot) < \gamma^D(\beta, \tau, \xi)$. \square

We observe in particular that $\beta^*(\pi, \tau, \xi)$ is a function of the spending policy as well as the size of the natural resource abundance. The larger direct transfers given to the young, $\pi\xi$, the more altruistic the parents must be to leave bequests, and the larger direct transfers given to the old, $(\tau - \pi)\xi$, less altruistic parents also leave bequests. In general, changes in ξ amplify differences in direct transfers across generations, and we give the following direct transfer distribution rules: When $\tau = \pi[(1 + \rho)(\frac{1-\alpha}{\alpha}) + 1]$, there is no effect on $\beta^*(\pi, \tau, \xi)$ from changes in ξ ; i.e., $\frac{\partial \beta^*(\pi, \tau, \xi)}{\partial \xi} = 0$, and when $\tau < (>)\pi[(1 + \rho)(\frac{1-\alpha}{\alpha}) + 1]$, $\frac{\partial \beta^*(\pi, \tau, \xi)}{\partial \xi} > (<)0$. Therefore, changes in ξ may push economies from one growth regime to another. In the following, we examine what happens to the growth rate when increases in ξ cause the economy to shift regime:

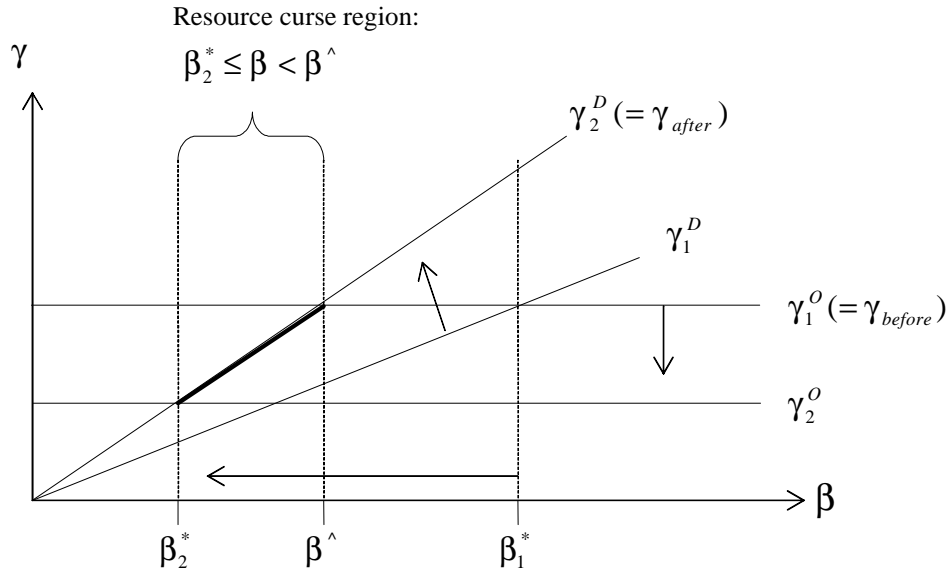


Figure 1: Impact on growth from changes in growth regime, prompted by an increase in natural resource abundance.

PROPOSITION 4. *There exist exogenous spending policies (τ, π) for which a change in growth regime invoked by increased natural resource abundance implies a resource curse. When the economy shifts from an overlapping generations regime to a dynastic regime due to increased natural resource abundance then growth can be lower in the new regime than in the old.*

PROOF. See appendix.

The situation where a resource curse can occur as a result of a change in growth regime induced by enhanced natural resource abundance is illustrated in fig. 1. In the figure, subscript “1” refers to the situation before - and subscript “2” refers to the situation after - an increase in natural resource abundance (i.e., in ξ). The horizontal lines illustrates the growth rate in the overlapping generations regime, γ^O , which is independent of the altruism factor (cf. (25)), and the growth rate in the infinitely lived agents regime, γ^D , which increases in β (cf. (29)).

Consider a situation in which before the change in natural resource abundance

$\beta < \beta_1^*$ and hence the economy evolves along γ_1^O . Now suppose that the natural resource abundance increases; that the spending policy is such that both the threshold altruism factor and the growth rate in the overlapping generations regime declines (to β_2^* and γ_2^O respectively); and moreover that $\beta_2^* \leq \beta$ so that the economy shifts to the dynastic regime, where the growth rate is given by γ_2^D . Then, as illustrated by the thicker part of γ_2^D , if $\beta < \beta^\wedge$, the growth rate declines. Interestingly, however, we also notice that growth declines less than it would have done otherwise without the regime shift, in which case the growth rate would be γ_2^O . Indeed, if $\beta \geq \beta^\wedge$ a potential resource curse situation (as described in lemma 1) is prevented by the regime shift as in this case $\gamma_2^D > \gamma_1^O$.

Summing up, this section illustrates that spending policies matter and that they matter differently depending on the presence of bequests. When spending policies are exogenous, the resource curse prevails as a consequence of savings decline. Finally, we note that the resource curse and welfare gains may be opposite sides of the same coin.

4 Political Equilibrium

It seems reasonable, however, to think of spending policies as typically endogenously determined by a specific economic or political agenda. Therefore, in this section we ask a slightly different question; namely, if there are economies in which the resource curse exist under endogenous policies. We examine specific policy objectives: growth maximizing policies, young and old policies.

4.1 Growth Maximizing Policies

LEMMA 2. *Let $\hat{\pi}^O$ and $\hat{\tau}^O$ be the growth maximizing policy when the public budget is given by the resource revenues (in (3)) and the economy is constrained to be without bequests. Then $\hat{\pi}^O = \tau$ and*

$$\hat{\tau}^O = \begin{cases} 0 & \text{if } 1 - \alpha - \frac{\alpha^2}{\xi} \leq 0 \\ 1 - \alpha - \frac{\alpha^2}{\xi} & \text{if } 1 - \alpha - \frac{\alpha^2}{\xi} > 0 \end{cases} .$$

PROOF. See Appendix.

The intuition for this result is as follows. When direct transfers are positive and given to the young, they influence the growth rate through two channels between which there is a trade-off. The higher τ , the larger direct transfers (to the young generation) which, *ceteris paribus*, leads to larger savings for retirement. The higher τ , however, the less public service input into private production. Lower public service input into production leads to lower marginal factor productivity, and lower wage rates means fewer savings for retirement.¹⁵

When $\pi = \hat{\pi}^O = \tau$ and $\tau = \hat{\tau}^O \equiv \hat{\tau}^O(\alpha, \xi)$, savings are maximized under the given public budget and generate the highest feasible growth rate in a no bequest environment. We notice, when the value of $\hat{\tau}^O(\alpha, \xi)$ is given by a corner solution, the rate of economic growth will increase further if the government is able to collect lump-sum taxes to expand the public service. In such a situation the size of the public service flow is sub-optimal.

Notice also $\frac{\partial \hat{\tau}^O(\alpha, \xi)}{\partial \xi} > 0$ when $1 - \alpha - \frac{\alpha^2}{\xi} > 0$. This means that the more abundant the resource, a larger share of the revenues is given as direct transfers in order to maximize growth. The reason is that the larger ξ , the higher the value of one unit of direct transfer. Higher costs, in terms of lower factor payments, can therefore be tolerated; i.e., the benefits exceed the costs up until the new policy rule.

LEMMA 3. *Let $\hat{\tau}^D$ be the growth maximizing policy when the public budget is given by the resource revenues (in (3)) and the economy is constrained to be with positive bequests. Then $\hat{\tau}^D = 0$.*

PROOF. Because $\frac{\partial \gamma^D(\beta, \tau, \xi)}{\partial \tau} = \beta \frac{\partial r(\tau, \xi)}{\partial \tau} < 0$ we have that $\hat{\tau}^D = 0$. \square

In the infinitely-lived generations' environment, the growth maximizing policy is independent of the magnitude of the natural resource abundance; letting resource

¹⁵Moreover, less public service input into production means less man-made output. Since resource revenues are a fixed fraction of total output, this effect feeds back into lowering the total amount of resource revenues to be distributed in the first place. This externality, however, is not internalized in the competitive equilibrium.

revenues work as input into production leads to higher growth rates, since the rate of return is highest, when direct transfers τ are zero.

Combining lemma 2 and 3, it can be shown that when $\xi \leq \frac{\alpha^2}{1-\alpha}$, the growth maximizing policy is identical for the two growth regimes, namely zero direct transfers.

PROPOSITION 5. *Under growth maximizing policies, a resource curse does not exist; increased natural resource abundance enhances growth.*

PROOF. See Appendix.

The growth maximizing spending policy depends on the strength of altruism. For high values of the altruism factor, in order to enhance growth, all resource revenues are invested in public services, and for low values of altruism, the growth maximizing policy is to allocate a share of the natural resource revenues as direct transfers to the young.

Growth maximizing policies may, however, suffer from another potential problem: dynamic inefficiency. When bequests are absent, the only way for the young to provide for themselves when old, is to save, which they may do even if the interest rate is very low. In this case, transferring resources from the young generation to the old generation is Pareto efficient.

Dynamic inefficiency in endogenous growth models occurs when the competitive real rate of interest falls short of the growth rate (King and Ferguson 1993). This condition corresponds to $\beta^*(\cdot) > 1$.¹⁶ Under growth maximizing policies, if, e.g., $\hat{\pi}^O = \hat{\tau}^O = 1 - \alpha - \frac{\alpha^2}{\xi}$, then $\beta^*(\hat{\pi}^O, \hat{\tau}^O, \xi) = \frac{\rho(\alpha+\xi)}{1+\rho}$; therefore, in this case, growth maximizing policies trigger dynamic inefficiency when $\rho > \frac{1}{\alpha+\xi-1}$ and bequests are absent.

4.2 Young and Old Policies

In this section, either the young or the old decide a policy, which is implemented by the government. The policy remains unaltered in perpetuity,¹⁷ and the policy

¹⁶ $\gamma^O(\pi, \tau, \xi) > r(\tau, \xi) \Leftrightarrow \beta^*(\xi, \cdot)(1-a)f(\tau, \xi) - 1 > (1-a)f(\tau, \xi) - 1 \Leftrightarrow \beta^*(\xi, \cdot) > 1$.

¹⁷A similar assumption is made in Alesina and Rodrik (1994).

decision is made at the beginning of some arbitrary initial period. After determining the policy, the young earn a wage and decide their savings knowing whether they receive a direct transfer from the government or bequests or both. The old receive a return on their savings, possibly receive a direct transfer from the government, and possibly leave bequests.

At time t , the utility of a young person is given as in (9):

$$\bar{V}_t = \sum_{i=0}^{\infty} \beta^i [\ln(c_{1t+i}) + \rho \ln(c_{2t+1+i})], \quad (35)$$

$$= \frac{1}{1-\beta} \left\{ \ln(c_{1t}) + \rho \ln(c_{2t}) + \left(\frac{\beta + \rho}{1-\beta} \right) \ln[1 + \gamma] \right\}. \quad (36)$$

The young derive utility of own consumption both as young and as old as well of consumption of their heirs. The old, on the other hand, only derive utility of own consumption as old and of consumption of their heirs:

$$\underline{V}_t = \ln(c_{2t}) + \sum_{i=0}^{\infty} \beta^{1+i} [\ln(c_{1t+i}) + \rho \ln(c_{2t+1+i})], \quad (37)$$

$$= \ln(c_{2t}) + \frac{\beta}{1-\beta} \left\{ \ln(c_{1t}) + \rho \ln(c_{2t}) + \left(\frac{\beta + \rho}{1-\beta} \right) \ln[1 + \gamma] \right\}. \quad (38)$$

Nevertheless,

PROPOSITION 6. *The resource curse can exist when individuals have “a very small” altruism factor and spending policies are decided by an old generation.*

PROOF. See Appendix.

When the economy is borderline “non-altruistic,” a policy decided by the old can trigger a resource curse. This may not be surprising in that the old generation care overridingly about its own consumption. Yet since the old receive a higher return to savings the higher the rate of return, the old do not claim all resource revenues. A part, if not all, of the revenue is still allocated to public services. Therefore, a “non-altruistic” economy ruled by the old is not automatically cursed.

Unfortunately, finding closed form solutions to the welfare maximizing policy of either generation cannot seem to be done in this model. By imposing an additional assumption to the problem, however, we are able to obtain such results.

ASSUMPTION 1. $\pi = \tau$. (*Only the young receive direct transfers from the government.*)

As the assumption exogenously determines the intergenerational allocation of potential direct transfers from the government, we refer to policies under assumption 1 as “quasi-endogenous” spending policies. In the following, *young policies* and *old policies*, i.e., the policies that the young or the old implement in order to maximize their welfare, are accordingly “quasi-endogenous” spending policies.

Assumption 1 is not binding when bequests are positive, since any change in the distribution of direct transfers of natural resource revenues across generations is offset by an opposite change in bequests. Assumption 1 does, however, affect the threshold altruism factor positively, which pushes economies towards being in the overlapping generations’ regime.

Under assumption 1, let $\bar{\tau}$ and $\underline{\tau}$ denote the policy that maximizes \bar{V}_t and \underline{V}_t given the size of the public budget given by the resource revenues. When $\bar{\tau}$ and $\underline{\tau}$ are zero, utility will increase further if the government collects lump-sum payments to increase the size of the public service. In this case, expanded public services increase the wage rate and the return to capital, which leads to an overall increase in utility. We analyze this possibility in the next section, but for now, the maximum size of the public service is bounded from above by inflows of natural resource revenues, as under growth maximizing policies.

Let $\bar{\tau}^O$ be the spending policy that maximizes young welfare subject to the public budget restriction when the economy is constrained to be without bequests, and let $\bar{\tau}^D$ be the spending policy that maximizes young welfare, also subject to the public budget restriction, when the economy is constrained to be with positive bequests. Moreover, define $\bar{\chi}^O \equiv \frac{1+\rho}{\rho(1-\beta)+1+\rho} \frac{1-\alpha}{\alpha}$ and $\bar{\chi}^D \equiv (1-\beta)\bar{\chi}^O$. Then, *under assumption 1*,

LEMMA 4. *Young policy when the economy is constrained to be in either growth*

regime:

$$\bar{\tau}^O = \begin{cases} 0 & \text{if } \xi \bar{\chi}^O \leq \alpha \\ \frac{\xi \bar{\chi}^O - \alpha}{\xi(1 + \bar{\chi}^O)} & \text{if } \xi \bar{\chi}^O > \alpha \end{cases} \quad \text{and} \quad \bar{\tau}^D = \begin{cases} 0 & \text{if } \xi \bar{\chi}^D \leq 1 - \beta(1 - \alpha) \\ \frac{\xi \bar{\chi}^D - [1 - \beta(1 - \alpha)]}{\xi(1 + \bar{\chi}^D)} & \text{if } \xi \bar{\chi}^D > 1 - \beta(1 - \alpha) \end{cases} .$$

PROOF. See Appendix.

Likewise, subject to the public budget restriction, let $\underline{\tau}^O$ be the spending policy that maximizes welfare of the old generation when the economy is constrained to be without bequests, and let $\underline{\tau}^D$ be the spending policy that maximizes old welfare when the economy is constrained to be with positive bequests. Moreover, define $\underline{\chi}^O \equiv \frac{1 + \rho}{\frac{(1 - \beta)^2}{\beta} + \rho(1 - \beta) + 1 + \rho} \frac{1 - \alpha}{\alpha}$ and $\underline{\chi}^D \equiv \frac{(1 - \beta)(\frac{1 + \beta \rho}{\beta})}{\frac{(1 - \beta)^2}{\beta} + \rho(1 - \beta) + 1 + \rho} \frac{1 - \alpha}{\alpha}$. Then, *under assumption 1*,

LEMMA 5. *Old policy when the economy is constrained to be in either growth regime:*

$$\underline{\tau}^O = \begin{cases} 0 & \text{if } \xi \underline{\chi}^O \leq \alpha \\ \frac{\xi \underline{\chi}^O - \alpha}{\xi(1 + \underline{\chi}^O)} & \text{if } \xi \underline{\chi}^O > \alpha \end{cases} \quad \text{and} \quad \underline{\tau}^D = \begin{cases} 0 & \text{if } \xi \underline{\chi}^D \leq 1 - \beta(1 - \alpha) \\ \frac{\xi \underline{\chi}^D - [1 - \beta(1 - \alpha)]}{\xi(1 + \underline{\chi}^D)} & \text{if } \xi \underline{\chi}^D > 1 - \beta(1 - \alpha) \end{cases} .$$

PROOF. See Appendix.

We notice that the young and old spending policies, $\bar{\tau}$ and $\underline{\tau}$, are both functions of the intertemporal and intergenerational discount factors as well as of resource abundance; $\bar{\tau} \equiv \bar{\tau}(\bar{\chi}, \xi)$ and $\underline{\tau} \equiv \underline{\tau}(\underline{\chi}, \xi)$.

In both growth regimes, the marginal loss of increasing direct transfers is a decline in public service input into production, which channels into lower factor payments. The trade-off faced by the individual depends on the weights given in her welfare function, which, in turn, depends on whether she is young or old, and the growth dynamics. For example, when bequests are absent, all things equal, the young are more likely to implement a spending policy that involves direct transfers; $\bar{\chi}^O > \underline{\chi}^O$, $\frac{\partial \bar{\tau}^O(\cdot)}{\partial \bar{\chi}^O} > 0$ and $\frac{\partial \underline{\tau}^O(\cdot)}{\partial \underline{\chi}^O} > 0$. The young generations value the utility of own consumption in their utility function undiscounted, whereas the old discount the offspring's utility of young consumption using the intergenerational discount factor.

The marginal utility the young obtain from direct transfers is therefore higher and offsets higher marginal utility costs which the direct transfers impose.

Moreover, *under assumption 1*,

PROPOSITION 7. *Within either growth regime, a resource curse does not exist under either young or old policies; increased natural resource abundance enhances growth.*

PROOF. See Appendix.

Furthermore, it is straightforward to show that under assumption 1, increased natural resource abundance increases welfare of the young and the old under both a young and an old policy, when the growth regime remains unaltered. Under both policies, $\frac{\partial c_{1t}^O(\xi, \cdot)}{\partial \xi} > 0$, $\frac{\partial c_{1t}^D(\xi, \cdot)}{\partial \xi} > 0$, $\frac{\partial c_{2t}^O(\xi, \cdot)}{\partial \xi} > 0$, $\frac{\partial c_{2t}^D(\xi, \cdot)}{\partial \xi} > 0$, and by proposition 7, $\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} > 0$ and $\frac{\partial \gamma^D(\xi, \cdot)}{\partial \xi} > 0$, so by (36) and (38) we have that within either regime $\frac{\partial V_t}{\partial \xi} > 0$ and $\frac{\partial \bar{V}_t}{\partial \xi} > 0 \forall \pi = \tau$ and $0 \leq \tau < 1$.

Lemma 4 and 5 imply that young and old policies are likely to vary, which means that also growth rates may vary across political regimes. An economy under either a young or an old policy may grow faster in either regime. We notice also that young and old policies differ from growth maximizing policies (derived in lemma 2 and 3), when direct transfers are present. On the other hand, policies decided by the young, the old, as well as growth maximizing policies are coincident, when direct transfers are zero.

4.2.1 Growth Regime Shifts and the Resource Curse

The “quasi-endogenous” spending policies of an economy ruled by the young or the old laid out in lemma 4 and 5 are policies which are constrained by presence or absence of bequests. This section illustrates that the young or the old may be able to, through their policies, determine whether bequests are present or not, and unlike growth maximizing policies, young or old policies can imply a resource curse.

It suffices to analyze either of the above “quasi-endogenous” policies, since the mechanism is the same. We choose to analyze an economy ruled by the young and

apply a numerical example given by $\beta = 0.3$,¹⁸ $\alpha = 0.33$ and $\rho = 0.55$,¹⁹ so that $\bar{\chi}^O = 1.60$ and $\bar{\chi}^D = 1.12$ by lemma 4.

For the parameter values chosen for this example, a young policy, which is constrained by positive bequests, involves positive transfers when resource abundance is high (when the condition in lemma 4, $\xi\bar{\chi}^D > 1 - \beta(1 - \alpha)$, is fulfilled) and, accordingly, $\beta^*(\bar{\tau}^D(\xi, \cdot), \xi)$ grows as parents must be increasingly altruistic to leave positive bequests. The possibility of positive bequests remains, however, since $\beta^*(\bar{\tau}^D(\xi, \cdot), \xi) < \beta$ for all values of $0 < \xi < 1$ in the example. Yet at a certain level of resource abundance, the economy could also be in the overlapping generations' growth regime. At these levels of resource abundance, direct transfers under a no bequest constrained young policy would involve transfers so high that parents would not leave bequests. Interestingly, therefore, the economy, for values of ξ high enough, could be on a growth path with zero or with positive bequests. The young, therefore, must compare welfare levels to determine the regime in which to set young policy which is not constrained by presence or absence of bequests.

Fig. 2 maps utility levels of a representative young individual under either growth regime along with the corresponding growth rates at different values of ξ . Both utility levels and growth rates of either regime increase in ξ . We only map utility and growth rate in the overlapping generations' regime for "relevant" values of ξ , that is, when the economy could be in this regime under young policy (i.e., when $\xi > \xi^*$ where ξ^* is the value taken by ξ when $\beta^* = \beta$, i.e., $\xi^* = \frac{\{\beta(1+\rho)(1-\alpha)/\rho\} - \alpha}{\bar{\chi}^O} + \alpha$).²⁰

Utility levels are illustrated by the thick lines and thus the line, which crosses from below, illustrates utility levels for the overlapping generations regime, whereas the other - kinked - line, illustrates utility levels for the dynastic regime. The kink occurs then direct transfers become positive. At this point, a smaller share of the

¹⁸This value is taken from Croix and Michel (2002, 255).

¹⁹Assuming each period is 30 years, this corresponds to an annual discount rate of 2 percent.

²⁰To see this, let $\beta^* = \frac{\rho(\alpha + \bar{\tau}^O \xi)}{(1+\rho)(1-\alpha)}$ under young policy. As $\beta = 0.3 = \beta^*(\xi^*)$ requires $\bar{\tau}^O > 0$, substituting $\bar{\tau}^O = \frac{\xi^* \bar{\chi}^O - \alpha}{\xi^*(1 + \bar{\chi}^O)}$, and solving for ξ^* yields $\xi^* = \frac{\{\beta(1+\rho)(1-\alpha)/\rho\} - \alpha}{\bar{\chi}^O} + \alpha$.

resource revenue is allocated to productive public services and the direct transfers from the government to the young are offset by a decline in parents' bequests. Therefore, the growth rate increases at a slower rate when ξ gets higher. The fact that both consumption as young and old, as well as the growth rate, enters the welfare function of the young given in (36), explains the kink.

Growth rates; Utility

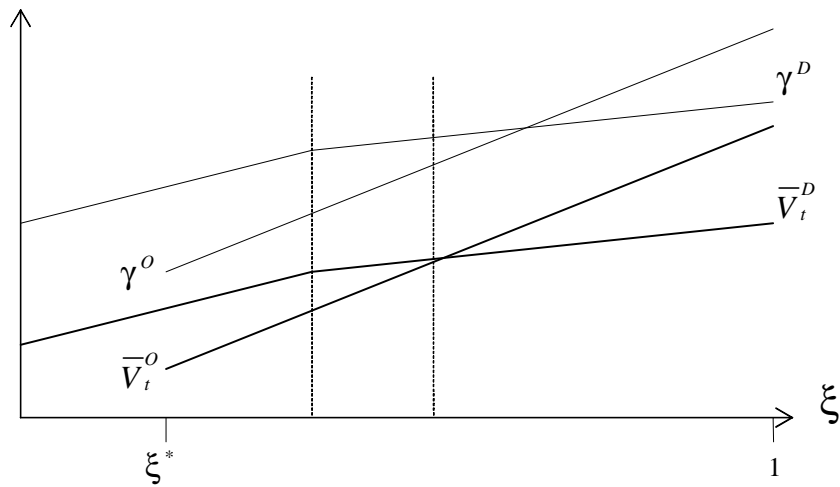


Figure 2: Growth rates and utility levels for a young person under different policies considered by a young policy maker at different levels of natural resource abundance.

Assuming that the productivity term A is large enough that growth is positive, growth rates are illustrated by the thin lines in fig. 2. The line, which starts at $\xi = \xi^*$, illustrates the growth rate for under the no bequest regime, and the line, which it crosses, illustrates the growth rate of the dynastic regime. Generally, the growth rates vary across growth regimes, and, we notice, that the dynastic growth rate has the kink that corresponds to the level of revenues at which positive direct transfers set in. Comparing utility levels, as ξ becomes higher, there is a utility gain for the young person from shifting from the dynastic regime to overlapping generations regime. By shifting growth regime, as natural resources become more

abundant, the young receives a larger direct transfer from the government, which, despite at the expense of bequests, leads to higher consumption levels as young, and, despite the drop in the growth rate, in higher welfare levels.

Indeed, the depicted economy experiences a decline in the growth rate, when, in response to higher resource revenues, the young policy maker decides a policy which shifts the economy from the dynastic regime to the overlapping generations' regime with a lower growth rate.

5 The Optimal Policy

This section introduces a social planner, who's objective is to maximize welfare, W_t , of current and all future generations. The role for a social planner is threefold as the model has three sources of inequality between the social planner equilibrium and the market equilibrium. First, the positive effect on GDP from man-made production, in the form of increased resource revenue, is external to the producers leading to under-saving and under-accumulation of capital. Second, in the market equilibrium, investments in the public service are restricted by the available budget, namely the resource revenues, and there may be economies for which an optimal size of public service flow is not feasible. Lastly, we noted that when bequests are absent, the competitive equilibrium may be dynamically inefficient.

Welfare at time $t = 0$, W_0 , is given as a weighted sum of current and future utilities of the members of society by a social welfare function that can be presented as

$$W_0 = \rho \ln(c_{20}) + \sum_{t=0}^{\infty} \beta^{t+1} [\ln(c_{1t}) + \rho \ln(c_{2t+1})], \quad (39)$$

where β is the planner's intergenerational discount factor.²¹

The social planner runs a balanced budget, and the resource constraint is the same as in the market economy, given by

$$(1 + \xi)y_t = c_{1t} + c_{2t} + k_{t+1} + g_t, \quad (40)$$

²¹For simplicity, the private intergenerational discount factor equals that of the social planner. In principle, they could differ.

with initial capital $k_0 > 0$. The variable g_t denotes the level of public service chosen by the social planner. Using this constraint, and substituting c_{1t} , (39) can be rewritten as

$$W_0 = \rho \ln(c_{20}) + \sum_{t=0}^{\infty} \beta^{t+1} \ln \{[(1 + \xi)y_t - c_{2t} - k_{t+1} - g_t] + \rho \ln(c_{2t+1})\}. \quad (41)$$

The necessary transversality condition is given by

$$\lim_{t \rightarrow \infty} \beta^t q_t k_t = 0, \quad (42)$$

where q_t is the shadow price of the capital stock. Equation (42) ensures that the discounted value of wealth tends to zero and that (39) converges (Croix and Michel 2002, 252).

The solution to the social planners problem is found by differentiating (41) with respect to c_{2t} , k_{t+1} , and g_t . We obtain the following conditions satisfied for all periods, t :

$$\frac{\beta}{c_{1t}} = \frac{\rho}{c_{2t}}, \quad (43)$$

and

$$\frac{1}{c_{1t}} = \frac{\beta[(1 + \xi)\frac{\partial y_t}{\partial k_t}]}{c_{1t+1}}. \quad (44)$$

Equation (43) says that the ratio between the utility of consumption of the young and the old generation must equal the ratio between the intertemporal and intergenerational discount factor. Unlike the solution to the altruistic generations' problem, this equation must hold, since otherwise welfare would increase by shifting consumption across generations. Equation (44) says that the ratio between utility of young consumption in two consecutive periods must equal the intergenerational discount rate multiplied with the gross return on capital, since this is the return to savings. As capital fully depreciates, the social return to capital, r_t^{sp} , is

$$(1 + \xi)\frac{\partial y_t}{\partial k_t} = (1 + \xi)(1 - \alpha)\frac{y_t}{k_t} = 1 + r_t^{sp}, \quad (45)$$

so (44) can be rewritten as

$$\frac{1}{c_{1t}} = \frac{\beta(1 + r_t^{sp})}{c_{1t+1}}. \quad (46)$$

The social planner chooses an optimal public service flow that satisfies

$$(1 + \xi) \frac{\partial y_t}{\partial g_t} = 1. \quad (47)$$

In optimum, the marginal benefit of increasing the public service, the rise in man-made output plus resource revenues, is exactly equal to the cost of doing so. By use of (4), (47) can be expressed as

$$g_t = \alpha(1 + \xi)y_t. \quad (48)$$

As g_t is a constant fraction of y_t , in optimum, the public spending output ratio is constant. Applying this expression of g_t , we can rewrite (4) as

$$y_t = Ak_t \left[\frac{\alpha(1 + \xi)y_t}{k_t} \right]^\alpha \Leftrightarrow y_t = [A\alpha^\alpha(1 + \xi)^\alpha]^\frac{1}{1-\alpha} k_t \equiv f^{sp}(\xi)k_t. \quad (49)$$

Using (49), we can express r_t^{sp} from (45)

$$r_t^{sp} = (1 + \xi)(1 - \alpha)f^{sp}(\xi) - 1 \equiv r^{sp}(\xi). \quad (50)$$

By (46), the growth rate in the consumption of the young generation, γ_{t+1} , is

$$\gamma_{t+1} = \beta[1 + r^{sp}(\xi)] - 1 \equiv \gamma(\xi). \quad (51)$$

We define an optimal balanced growth path as a path along which c_{1t} , c_{2t} , k_t , y_t , g_t , and e_t grow at a constant relative rates, $\gamma(\xi)$, at all periods $t > 0$. From (49) it follows that capital grows at the same rate as output. Since resource revenues are given as a fixed fraction of output (in (1)), it follows immediately that the inflow of natural resource revenues grows at the same rate as output. Moreover, as public services are given as a fixed fraction of total resource revenues (in (57)), also public services grow at the rate of output.

By the resource constraint (in (40)) and (50) it must be that if capital and output grow at the same rate, then this rate equals that of consumption. From (43), we know that the ratio of young and old consumption is constant; thus, old consumption grows at the same rate as young consumption.

It can be shown that q_t equals $\frac{1}{c_{1t-1}}$ (Croix and Michel 2002, 103) and therefore decreases at the rate $\gamma(\xi)$, and the transversality condition in (16) simplifies to $\beta < 1$. To ensure non-negative growth, we assume that $\beta \geq \frac{1}{1+r^{sp}(\xi)}$. The economy has no transitional economics; c_{1t} , c_{2t} , k_t , y_t , g_t , and e_t are an optimal solution to the social planners problem and grow at the same rate along a balanced growth path at all periods, where (51) characterizes the balanced growth path. Along such a path, equilibrium is given by

$$c_{1t} = \frac{\beta(1-\beta)}{\beta+\rho}(1+\xi)(1-\alpha)f^{sp}(\xi)k_t \equiv c_{1t}(\xi), \quad (52)$$

$$c_{2t} = \frac{\rho(1-\beta)}{\beta+\rho}(1+\xi)(1-\alpha)f^{sp}(\xi)k_t \equiv c_{2t}(\xi), \quad (53)$$

$$k_{t+1} = \beta(1+\xi)(1-\alpha)f^{sp}(\xi)k_t \equiv k_{t+1}(\xi), \quad (54)$$

with $k_0 > 0$ given.

5.1 Decentralization

We proceed to show how the social planner may decentralize the optimal solution just derived. Decentralization requires three policy instruments since one externality has to be internalized, public services have to be financed, and the competitive equilibrium may be dynamically inefficient.

To internalize the spillover effect from man-made production onto resource revenues, the social planner subsidizes the firms with the resource inflow. The representative firm solves

$$\max_{K_t, L} \left\{ (1+\xi)AK_t^{1-\alpha}(g_tL)^\alpha - r_tK_t - w_tL \right\}, \quad (55)$$

taking g_t , r_t , and w_t as given. Hence, from the standpoint of the firm,

$$r_t = (1+\xi)(1-\alpha)f^{sp}(\xi) - 1 = r^{sp}(\xi), \quad (56)$$

and the private marginal return to capital coincides with the social marginal return.

As resource revenues are allocated to the firms, the social planner collects lump-sum taxes to invest in the public service. It is convenient to let the tax be a share

of GDP, so

$$\tilde{\tau}(1 + \xi)y_t = g_t, \quad (57)$$

where the lump-sum tax rate, $\tilde{\tau}$, is a constant. It follows from the balanced budget that $0 < \tilde{\tau} < 1$. The social planner collects a share, $\tilde{\pi}$, of the tax payments from the young generation and the rest, $(1 - \tilde{\pi})$, from the old generation. An altruistic individual is now faced with the following budget constraint:

$$c_{1t} + s_t = b_t + w_t - \tilde{\pi}g_t, \quad (58)$$

when young, and

$$c_{2t+1} + b_{t+1} = [1 + r^{sp}(\xi, \cdot)]s_t - (1 - \tilde{\pi})g_{t+1}, \quad (59)$$

when old, where the real wage rate, w_t , can be derived from (55), and $b_t \geq 0$.

LEMMA 6. *Let $\tilde{\pi}$ and $\tilde{\tau}$ be a policy that decentralizes the resource allocation chosen by the social planner. Then $\tilde{\tau} = \alpha$ and $\tilde{\pi} = 1 - \frac{1-\alpha}{\alpha} \frac{\beta(1+\rho)}{\beta+\rho}$.*

PROOF. The size of the public service is optimal when (48) equals (57). Hence, $\tilde{\tau} = \alpha$.

The transfer which ensures the competitive consumption path equals the optimal consumption path when bequests are absent satisfies for old consumption, by (59) and (53), that

$$[1 + r^{sp}(\xi)]k_t - (1 - \tilde{\pi})g_t = \frac{\rho(1 - \beta)}{\beta + \rho}(1 + \xi)(1 - \alpha)f^{sp}(\xi)k_t.$$

Substituting $r^{sp}(\xi)$, k_t , and g_t , and solving for $\tilde{\pi}$, we find $\tilde{\pi} = 1 - \frac{1-\alpha}{\alpha} \frac{\beta(1+\rho)}{\beta+\rho}$.

When bequests are positive, they are given by

$$b_t = (1 + \xi)f^{sp}(\xi)\left[(1 - \alpha)\frac{\beta(1 + \rho)}{\beta + \rho} - \alpha(1 - \tilde{\pi})\right]k_t$$

which is positive for $\tilde{\pi} > 1 - \frac{1-\alpha}{\alpha} \frac{\beta(1+\rho)}{\beta+\rho}$ and just zero when $\tilde{\pi} = 1 - \frac{1-\alpha}{\alpha} \frac{\beta(1+\rho)}{\beta+\rho}$. As

$$\frac{\partial b_t}{\partial \tilde{\pi}} = \alpha(1 + \xi)f^{sp}(\xi)k_t = g_t,$$

and as

$$c_{2t} = [1 + r^{sp}(\xi)]k_t - (1 - \tilde{\pi})g_t - b_t$$

so

$$\frac{\partial c_{2t}}{\partial \tilde{\pi}} = 0,$$

consumption is invariant to changes in $\tilde{\pi}$ as long as $\tilde{\pi} \geq 1 - \frac{1-\alpha}{\alpha} \frac{\beta(1+\rho)}{\beta+\rho}$. \square

The share, $\tilde{\pi}$, thus provides a lower bound on how little the young may be taxed and still leave the parent at least indifferent between leaving bequests or not. When $1 > \tilde{\pi} > 0$, both the old and the young contribute to the public service. When $\tilde{\pi} = 0$ only the old pay, and when $\tilde{\pi} < 0$, only the old pay and the young generation receives a transfer. The share, $\tilde{\pi}$, cannot be higher than one, since then the young would have negative consumption.

As we expect, an optimal balanced growth path is dynamically efficient. When $\tilde{\pi} = 1 - \frac{1-\alpha}{\alpha} \frac{\beta(1+\rho)}{\beta+\rho}$, parents are indifferent about leaving bequests and $\beta = \beta^*$. Since $\beta < 1$, the rate of return is higher than the rate of growth. Finally,

PROPOSITION 8. *Under optimal policies, welfare and growth increase when inflows of natural resource revenues increase.*

PROOF. By (39),

$$W_t = \rho \ln c_{2t} + \frac{1}{1-\beta} \left[\ln(c_{1t}) + \rho \ln(c_{2t+1}) + \frac{\beta(1+\rho)}{1-\beta} \ln(1 + \gamma(\xi)) \right].$$

As $\frac{\partial \gamma(\xi)}{\partial \xi} > 0$ we can conclude that the resource curse does not exist, and, further by $\frac{\partial c_{1t}(\xi)}{\partial \xi} > 0$ and $\frac{\partial c_{2t}(\xi)}{\partial \xi} > 0$, that $\frac{\partial W_t}{\partial \xi} > 0$. \square

6 Concluding Remarks

Using an endogenous growth model with altruistic overlapping generations, we explain why nations may respond differently to natural resource abundance: Nations may be in different growth regimes that vary in how savings are affected by natural resource revenues.

As first pointed out by Weil (1987), there is a threshold level of altruism which separates the two growth regimes. In our model, this threshold level of altruism, which is determined endogenously, is influenced by the allocation and the abundance

of the resources. When parents' altruism is higher than the threshold altruism level, the bequest motive is operative, and resource abundance increases growth as well as welfare of either generation. Bequests interrupt the connection between direct transfers from the government and savings by allowing for offsetting intergenerational transfers from the old to the young. Therefore, savings are unaffected by how resource revenues are allocated across generations. In contrast, a resource curse may exist when the bequests motive is not strong enough that parents leave bequests. In this case, policies that allocate revenues to the old generation may harm savings of the young and, subsequently, growth. Yet the effect on the current generation's welfare is ambiguous; resource abundance may increase consumption levels which then (perhaps more than) compensates for reduced growth.

We also examine spending policies that are endogenously determined by a specific economic or political agenda. We find that a resource curse is avoided by growth maximizing policies. Under such policies, when bequests are absent, any direct transfers are given exclusively to the young generation. Higher resource abundance merely increases direct transfers, and, hence, savings and growth. When bequests are positive, all revenues are allocated to public services, since, in a dynastic regime, growth expands with more public services. Public services, in turn, expand with the revenue under this spending policy.

Instead, a resource curse may be triggered by gerontocracy when altruism is "very small." The old generation may prefer to allocate to itself direct transfers to an extent that higher resource abundance reduces savings of the young generation.

We also examine spending policies decided by a young and an old generation respectively. Unfortunately, however, we can only find closed form solutions to the welfare maximizing spending policy of either generation when the old generation is excluded from receiving direct transfers. In this case, however, a decline in growth rates caused by increased resource abundance implies an increase in welfare. Thus, the general use of the term "poor economic performance" in relation to slower economic growth rates may be misleading. Nevertheless, by solving the social planner's problem, we show that under optimal policies there can never be a

resource curse as defined here.

Further theoretical work may seek to endogenize the policy decision which is modeled exogenously in this model. Such models will add to the literature on political economy explanations for the resource curse. Another extension is to examine other allocations of the resource revenue. In particular, a model in which the resource revenue is used only as direct transfers as suggested by Sala-i-Martin and Subramanian (2003) may lead to more explicit solutions. In addition, research into what factors, for instance, life-expectancy or fertility, that influence the strength of the bequest motive may be helpful in identifying how nations are affiliated with growth regimes, or development stages.

A Appendix

A.1 Proof of Proposition 2

We prove proposition 2 by presenting parameter combinations for which $\frac{\partial \gamma^O(\cdot)}{\partial \xi} < 0$ and, for both the young and the old generation, $\frac{\partial V_t}{\partial \xi} > 0$.

Utility of a representative young individual at time t in the overlapping generations' regime, \bar{V}_t^O , is given as

$$\bar{V}_t^O = \frac{1}{1-\beta} \left\{ \ln(c_{1t}^O) + \rho \ln(c_{2t}^O) + \left[\frac{\beta + \rho}{1-\beta} \right] \ln(1 + \gamma^O(\xi, \cdot)) \right\},$$

(this equation is the same as (36) in the main text), where

$$\frac{\partial \bar{V}_t^O}{\partial \xi} = \frac{1}{1-\beta} \left\{ \frac{\frac{\partial c_{1t}^O}{\partial \xi}}{c_{1t}^O} + \frac{\rho \frac{\partial c_{2t}^O}{\partial \xi}}{c_{2t}^O} + \left[\frac{\beta + \rho}{1-\beta} \right] \frac{\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi}}{1 + \gamma^O(\xi, \cdot)} \right\}. \quad (60)$$

Utility of a representative old individual at time t in the overlapping generations' regime, \underline{V}_t^O , is given as

$$\underline{V}_t^O = \ln(c_{2t}^O) + \frac{\beta}{1-\beta} \left\{ \ln(c_{1t}^O) + \rho \ln(c_{2t}^O) + \left[\frac{\beta + \rho}{1-\beta} \right] \ln(1 + \gamma^O(\xi, \cdot)) \right\},$$

(this equation is the same as (38) in the main text), where

$$\frac{\partial \underline{V}_t^O}{\partial \xi} = \frac{\frac{\partial c_{1t}^O}{\partial \xi}}{c_{1t}^O} + \frac{\beta}{1-\beta} \left\{ \frac{\frac{\partial c_{1t}^O}{\partial \xi}}{c_{1t}^O} + \frac{\rho \frac{\partial c_{2t}^O}{\partial \xi}}{c_{2t}^O} + \left[\frac{\beta + \rho}{1-\beta} \right] \frac{\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi}}{1 + \gamma^O(\xi, \cdot)} \right\}. \quad (61)$$

When $\pi = 0$, then

$$\frac{\frac{\partial c_{1t}^O}{\partial \xi}}{c_{1t}^O} = \frac{\alpha}{(1-\alpha)\xi} + \frac{\tau}{1-\alpha + \tau\xi} - \frac{\tau}{(1+\rho)(1-\alpha) + \tau\xi}, \quad (62)$$

and

$$\frac{\frac{\partial c_{2t}^O}{\partial \xi}}{c_{2t}^O} = \frac{\alpha}{(1-\alpha)\xi} + \frac{\tau}{1-\alpha + \tau\xi}, \quad (63)$$

and

$$\frac{\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi}}{1 + \gamma^O(\xi, \cdot)} = \frac{\alpha}{(1-\alpha)\xi} - \frac{\tau}{(1+\rho)(1-\alpha) + \tau\xi}. \quad (64)$$

Substituting (62), (63), and (64) in (60) and (61) gives

$$\frac{\partial \bar{V}_t^O}{\partial \xi} = \frac{1}{1-\beta} \left\{ \frac{\alpha \left[1 + \rho + \frac{\beta + \rho}{1-\beta} \right]}{(1-\alpha)\xi} + \frac{(1+\rho)\tau}{1-\alpha + \tau\xi} - \frac{\tau \left[\frac{1+\rho}{1-\beta} \right]}{(1+\rho)(1-\alpha) + \tau\xi} \right\},$$

and

$$\frac{\partial V_t^O}{\partial \xi} = \frac{\alpha}{(1-\alpha)\xi} + \frac{\tau}{1-\alpha+\tau\xi} + \beta \frac{\partial \bar{V}_t^O}{\partial \xi}.$$

We proceed by use of a numerical example in which $\alpha = 0.2$, $\rho = 0.5$, and $\beta = 0.1$.

By the proof of lemma 1, $\frac{\partial \gamma^O(\cdot)}{\partial \xi} < 0 \Leftrightarrow \tau(1-2\alpha) > \frac{(1-\alpha)\alpha}{\xi}(1+\rho)$. Hence, $\tau(1-2\alpha) > \frac{(1-\alpha)\alpha}{\xi}(1+\rho)$ implies for the numerical example that

$$\xi\tau > 0.4.$$

Moreover, $\frac{\partial \bar{V}_t^O}{\partial \xi} > 0$ implies

$$\frac{6.5}{3} + \frac{6\tau\xi}{0.8+\tau\xi} - \left(\frac{1}{0.9}\right) \frac{6\tau\xi}{1.2+\tau\xi} > 0,$$

and $\frac{\partial V_t^O}{\partial \xi} > 0$ implies

$$\frac{1}{4\xi} + \frac{\tau}{0.8+\tau\xi} + 0.1 \left[\frac{6.5}{3} + \frac{6\tau\xi}{0.8+\tau\xi} - \left(\frac{1}{0.9}\right) \frac{6\tau\xi}{1.2+\tau\xi} \right] > 0.$$

Since $\frac{1}{4\xi} + \frac{\tau}{0.8+\tau\xi} > 0$ then $\frac{\partial \bar{V}_t^O}{\partial \xi} > 0$ implies $\frac{\partial V_t^O}{\partial \xi} > 0$. Hence, we can focus on welfare of the young generation. We complete the proof by providing an example where $\xi\tau > 0.4$ and $\frac{6.5}{3} + \frac{6\tau\xi}{0.8+\tau\xi} - \left[\frac{1}{0.9}\right] \frac{6\tau\xi}{1.2+\tau\xi} > 0$. For example, $\xi\tau = 0.5 > 0.4$ satisfies the first condition, and $\xi\tau = 0.5 \Rightarrow \frac{6.5}{3} + \frac{3}{1.2} - \left(\frac{1}{0.9}\right) \frac{3}{1.7} = 2.7058 > 0$ satisfies the second condition. Hence, $\xi\tau = 0.5$ satisfies $\frac{\partial \gamma^O(\cdot)}{\partial \xi} < 0$, $\frac{\partial \bar{V}_t^O}{\partial \xi} > 0$ and $\frac{\partial V_t^O}{\partial \xi} > 0$. \square

A.2 Proof of Proposition 4

Combining (25) and (34) gives $\gamma^O(\xi, \cdot) = \beta^*(\xi, \cdot)(1-a)f(\tau, \xi) - 1$. Then,

$$\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} = \frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} [(1-a)f(\tau, \xi)] + \beta^*(\xi, \cdot)(1-a) \frac{\partial f(\tau, \xi)}{\partial \xi}.$$

where $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} = \frac{\rho}{(1+\rho)(1-\alpha)+(\tau-\pi)\xi} \left[\pi - \frac{(\alpha+\pi\xi)(\tau-\pi)}{(1+\rho)(1-\alpha)+(\tau-\pi)\xi} \right] \geq 0$ and $\frac{\partial f(\tau, \xi)}{\partial \xi} > 0$.

By (29), we derive

$$\frac{\partial \gamma^D(\xi, \cdot)}{\partial \xi} = \beta(1-a) \frac{\partial f(\tau, \xi)}{\partial \xi}.$$

where $\frac{\partial f(\tau, \xi)}{\partial \xi} > 0$.

There are three situations: $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} = 0$, $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} > 0$, and $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} < 0$.

First, when $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} = 0$, the growth regime remains unaltered by higher resource revenues (and $\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} > 0$ and $\frac{\partial \gamma^D(\xi, \cdot)}{\partial \xi} > 0$).

Second, when $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} > 0$, if an economy changes regime, it changes from a dynastic to an overlapping generations regime. When $\beta = \beta^*(\xi, \cdot)$, by definition, $\gamma^O(\xi, \cdot) = \gamma^D(\xi, \cdot)$ and thus when $\beta < \beta^*(\xi, \cdot)$, the initial growth rate $\gamma^D(\xi, \cdot)$ is less than $\gamma^O(\xi, \cdot)$. Hence, when the economy shifts from $\gamma^D(\xi, \cdot)$ to $\gamma^O(\xi, \cdot)$, and since $\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} > 0$ in this situation, the economy grows faster on the new growth path than on the old growth path.

Third, when $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} < 0$, if the economy changes regime, it changes from an overlapping generations regime to a dynastic regime. Again, when $\beta = \beta^*(\xi, \cdot)$, by definition, $\gamma^O(\xi, \cdot) = \gamma^D(\xi, \cdot)$.

Consider first the situation where $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} < 0$, but $\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} \geq 0$. Using the subscript “1” as a reference to the situation before and subscript “2” as a reference to the situation after an increase in natural resource abundance, then $\gamma_2^O(\xi, \cdot) \geq \gamma_1^O(\xi, \cdot)$. Since, for the regime shift to occur, $\beta > \beta_2^*(\xi, \cdot)$, and since when $\beta = \beta_2^*(\xi, \cdot)$ by definition $\gamma_2^O(\xi, \cdot) = \gamma_2^D(\xi, \cdot) (= \beta f(\tau, \xi_2)(1 - \alpha))$, we have that a regime shift implies $\gamma_2^D(\xi, \cdot) > \gamma_1^O(\xi, \cdot)$, i.e., the economy grows faster on the new growth path ($\gamma_2^D(\xi, \cdot)$) than on the old growth path ($\gamma_1^O(\xi, \cdot)$).

Now, consider the situation where $\frac{\partial \beta^*(\xi, \cdot)}{\partial \xi} < 0$ and $\frac{\partial \gamma^O(\xi, \cdot)}{\partial \xi} < 0$. Again, using the subscript “1” as a reference to the situation before and subscript “2” as a reference to the situation after an increase in natural resource abundance, then $\gamma_2^O(\xi, \cdot) < \gamma_1^O(\xi, \cdot)$. For the regime shift to occur, $\beta > \beta_2^*(\xi, \cdot)$, and since when $\beta = \beta_2^*(\xi, \cdot)$ by definition $\gamma_2^O(\xi, \cdot) = \gamma_2^D(\xi, \cdot) (= \beta f(\tau, \xi)(1 - \alpha))$ we have that growth is higher along the new growth path than along the old growth path, i.e., $\gamma_2^D(\xi, \cdot) \geq \gamma_1^O(\xi, \cdot)$, only if $\beta \geq \beta^\wedge$, where β^\wedge is defined as the value of the altruism factor for which $\gamma_1^O(\xi, \cdot) = \gamma_2^D(\xi, \cdot)$. If $\beta < \beta^\wedge$ the economy grows slower along the new growth path than along the old growth path. \square

A.3 Proof of Lemma 2

We consider the problem

$$\max_{\pi, \tau} \gamma^O(\pi, \tau, \xi) \text{ subject to } \pi \geq 0, \pi \leq \tau, \text{ and } \tau < 1.$$

The growth rate, $\gamma^O(\pi, \tau, \xi)$, is twice differentiable and concave and the restrictions are all linear. The Kuhn-Tucker conditions are thus both necessary and sufficient.

The Lagrangian is

$$\mathcal{L} = \frac{\rho(1-\alpha)f(\cdot)(\alpha + \pi\xi)}{(1+\rho)(1-\alpha) + (\tau - \pi)\xi} - 1 + \lambda_1\pi - \lambda_2(\pi - \tau) - \lambda_3(\tau - 1).$$

The five Kuhn-Tucker conditions are

$$\frac{\rho(1-\alpha)\xi f(\cdot)}{(1+\rho)(1-\alpha) + (\tau - \pi)\xi} \left[1 + \frac{\alpha + \pi\xi}{(1+\rho)(1-\alpha) + (\tau - \pi)\xi} \right] + \lambda_1 - \lambda_2 = 0 \quad (65)$$

$$\frac{\rho(1-\alpha)(\alpha + \pi\xi)}{(1+\rho)(1-\alpha) + (\tau - \pi)\xi} \left[\frac{\partial f(\cdot)}{\partial \tau} - \frac{f(\cdot)\xi}{(1+\rho)(1-\alpha) + (\tau - \pi)\xi} \right] + \lambda_2 - \lambda_3 = 0 \quad (66)$$

$$\lambda_1 \geq 0, \pi \geq 0, \lambda_1\pi = 0 \quad (67)$$

$$\lambda_2 \geq 0, \pi \leq \tau, \lambda_2(\pi - \tau) = 0 \quad (68)$$

$$\lambda_3 \geq 0, \tau < 1, \lambda_3(\tau - 1) = 0 \quad (69)$$

If $\pi = 0$ and $\tau = 0$ then $\lambda_3 = 0$. Combination of (65) and (66) yields

$$\lambda_1 = \frac{-\rho \left[\xi f(\cdot) + \frac{\partial f(\cdot)}{\partial \tau} \alpha \right]}{1 + \rho}.$$

Since $\lambda_1 \geq 0$, $\frac{\alpha^2}{\xi} \geq 1 - \alpha$ must be satisfied for this to be a solution. In this case,

$$\lambda_2 = \frac{\rho\xi f(\cdot)}{1 + \rho} + \frac{\rho f(\cdot)\alpha\xi}{(1 + \rho)^2(1 - \alpha)} + \lambda_1 > 0,$$

which is then a solution.

If $\pi = 0$ and $\tau > 0$, then $\lambda_2 = \lambda_3 = 0$. Hence, from (65)

$$\lambda_1 = -\frac{\rho(1-\alpha)\xi f(\cdot)}{(1+\rho)(1-\alpha) + \tau\xi} \left[1 + \frac{\alpha}{(1+\rho)(1-\alpha) + \tau\xi} \right],$$

which contradicts $\lambda_1 \geq 0$.

If $\pi > 0$ and $\tau > 0$, then $\lambda_1 = \lambda_3 = 0$. Hence, from (65) for this to be a solution, $\lambda_2 > 0$, and by (68), this requires $\pi = \tau$. Using (65) in (66), we have

$$\frac{\partial f(\cdot)}{\partial \tau}(\alpha + \tau\xi) + \xi f(\cdot) = 0,$$

which is satisfied when $\tau = 1 - \alpha - \frac{\alpha^2}{\xi}$.

We conclude that there are two solutions of the Kuhn-Tucker conditions:

$$\begin{aligned} (\pi, \tau, \lambda_1, \lambda_2, \lambda_3) &= \left(1 - \alpha - \frac{\alpha^2}{\xi}, 1 - \alpha - \frac{\alpha^2}{\xi}, 0, \frac{\rho\xi f(\cdot)}{1+\rho} + \frac{\rho f(\cdot)(\alpha+\pi\xi)\xi}{(1+\rho)^2(1-\alpha)}, 0\right) \text{ if } \frac{\alpha^2}{\xi} < 1 - \alpha, \text{ and} \\ (\pi, \tau, \lambda_1, \lambda_2, \lambda_3) &= \left(0, 0, \frac{-\rho[\xi f(\cdot) + \frac{\partial f(\cdot)}{\partial \tau}\alpha]}{1+\rho}, \frac{\rho\xi f(\cdot)}{1+\rho} + \frac{\rho f(\tau, \xi)\alpha\xi}{(1+\rho)^2(1-\alpha)} - \frac{\rho[\xi f(\cdot) + \frac{\partial f(\cdot)}{\partial \tau}\alpha]}{1+\rho}, 0\right) \text{ if} \\ &\frac{\alpha^2}{\xi} \geq 1 - \alpha. \quad \square \end{aligned}$$

A.4 Proof of Proposition 5

First, consider the economy without bequests. Let $\hat{\gamma}^O$ denote the growth rate under a growth maximizing spending policy when the economy is without bequests, then

$$\hat{\gamma}^O = \hat{\beta}^* (1 - \alpha) \hat{f}^O - 1 \equiv \hat{\gamma}^O(\hat{\pi}^O, \hat{\tau}^O, \xi), \quad (70)$$

where $\hat{\beta}^* \equiv \beta^*(\hat{\pi}^O, \hat{\tau}^O, \xi) = \frac{\rho(\alpha + \hat{\tau}^O \xi)}{(1+\rho)(1-\alpha)}$ and $\hat{f}^O \equiv f(\hat{\tau}^O, \xi)$. Direct transfers may be zero or positive: When $\hat{\pi}^O = \hat{\tau}^O = 0$, then

$$\frac{\partial \hat{\gamma}^O(\cdot)}{\partial \xi} = (1 - \alpha) \left[\frac{\rho\alpha}{1+\rho} \frac{\partial \hat{f}^O}{\partial \xi} \right] > 0;$$

When, $\hat{\pi}^O = \hat{\tau}^O = 1 - \alpha - \frac{\alpha^2}{\xi}$, then

$$\frac{d\hat{\gamma}^O(\cdot)}{d\xi} = (1 - \alpha) \left[\frac{\partial \hat{\beta}^*}{\partial \hat{\tau}^O} \frac{d\hat{\tau}^O}{d\xi} \hat{f}^O + \hat{\beta}^* \frac{\partial \hat{f}^O}{\partial \hat{\tau}^O} \frac{d\hat{\tau}^O}{d\xi} \right].$$

Since $\frac{\partial \hat{\beta}^*}{\partial \hat{\tau}^O} \frac{d\hat{\tau}^O}{d\xi} > 0$ and $\frac{\partial \hat{f}^O}{\partial \hat{\tau}^O} \frac{d\hat{\tau}^O}{d\xi} > 0$, we have that $\frac{d\hat{\gamma}^O(\cdot)}{d\xi} > 0$.

Second, let $\hat{\gamma}^D$ denote the growth rate when the economy is dynastic, thus

$$\hat{\gamma}^D = \beta(1 - \alpha) \hat{f}^D - 1 \equiv \hat{\gamma}^D(\hat{\tau}^D, \xi),$$

where $\hat{f}^D \equiv f(\hat{\tau}^D, \xi)$. Since $\hat{\tau}^D = 0$,

$$\frac{\partial \hat{\gamma}^D(\cdot)}{\partial \xi} = \beta(1 - \alpha) \frac{\partial \hat{f}^D}{\partial \xi} > 0.$$

Third, we consider the situation where the economy is in different growth regimes before and after the change in natural resource endowments. In this case,

$$\widehat{\beta}_{(\widehat{\tau}^O=0)}^* < \beta < \widehat{\beta}_{(\widehat{\tau}^O=1-\alpha-\frac{\alpha^2}{\xi})}^* \Leftrightarrow \frac{\rho\alpha}{(1+\rho)(1-\alpha)} < \beta < \frac{\rho[\alpha+\xi]}{(1+\rho)(1-\alpha)},$$

so that spending policies decide whether bequests are absent or present. Since $\frac{\partial \widehat{\beta}_{(\widehat{\tau}^O=0)}^*}{\partial \xi} = 0$ and $\frac{\partial \widehat{\beta}_{(\widehat{\tau}^O=1-\alpha-\frac{\alpha^2}{\xi})}^*}{\partial \xi} > 0$ the economy will be in the dynastic growth regime when direct transfers are absent at all levels of natural resource abundance.

Using the subscript “1” as a reference to the situation before and subscript “2” as a reference to the situation after an increase in natural resource abundance, consider first the situation where initially the growth maximizing policy is to let $\widehat{\tau}^O = 0$ and thus initially the economy evolves along $\widehat{\gamma}_1^D$. When policies are growth maximizing, the new growth regime will be the overlapping generations regime only if $\widehat{\gamma}_2^O > \widehat{\gamma}_2^D \Rightarrow \widehat{\gamma}_2^O > \widehat{\gamma}_1^D$ since $\frac{\partial \widehat{\gamma}_2^D(\cdot)}{\partial \xi} > 0$. Hence, growth is higher on the new growth path than on the old. Else, if $\widehat{\gamma}_2^O < \widehat{\gamma}_2^D$, there will be no regime shift, and cf. above, growth increases along the initial growth path (since $\frac{\partial \widehat{\gamma}_2^D(\cdot)}{\partial \xi} > 0$).

Now, consider the situation where initially the growth maximizing policy is to let $\widehat{\tau}^O = 1 - \alpha - \frac{\alpha^2}{\xi}$, and thus initially the economy evolves along $\widehat{\gamma}_1^O$. When policies are growth maximizing, the new growth regime will be dynastic only if $\widehat{\gamma}_2^D > \widehat{\gamma}_2^O \Rightarrow \widehat{\gamma}_2^D > \widehat{\gamma}_1^O$ since $\frac{\partial \widehat{\gamma}_2^O(\cdot)}{\partial \xi} > 0$. Hence, growth is higher on the new growth path than on the old. If $\widehat{\gamma}_2^D < \widehat{\gamma}_2^O$, there will be no regime shift, and cf. above, growth increases along the initial growth path.

Thus, there is no resource curse under growth maximizing policies. \square

A.5 Proof of Proposition 6

We consider the problem

$$\max_{\pi, \tau} \underline{V}_t^O \text{ subject to } \pi \geq 0, \pi \leq \tau, \text{ and } \tau < 1.$$

First, we choose $\beta = 0$, then $\underline{V}_t^O = \ln(c_{2t}^O) = \ln \{f(\tau, \xi)[1 - \alpha + (\tau - \pi)\xi]k_t^O\}$. Utility, \underline{V}_t^O , is twice differentiable and concave and the restrictions are all linear. The Kuhn-Tucker conditions are thus both necessary and sufficient. The Lagrangian

is

$$\mathcal{L} = \ln \{f(\tau, \xi)[1 - \alpha + (\tau - \pi)\xi]k_t^O\} + \lambda_1\pi - \lambda_2(\pi - \tau) - \lambda_3(\tau - 1).$$

The five Kuhn-Tucker conditions are

$$\frac{-\xi}{1 - \alpha + (\tau - \pi)\xi} + \lambda_1 - \lambda_2 = 0 \quad (71)$$

$$\frac{\xi}{1 - \alpha + (\tau - \pi)\xi} - \frac{\alpha}{1 - \alpha} \frac{1}{1 - \tau} + \lambda_2 - \lambda_3 = 0 \quad (72)$$

$$\lambda_1 \geq 0, \pi \geq 0, \lambda_1\pi = 0 \quad (73)$$

$$\lambda_2 \geq 0, \pi \leq \tau, \lambda_2(\pi - \tau) = 0 \quad (74)$$

$$\lambda_3 \geq 0, \tau < 1, \lambda_3(\tau - 1) = 0 \quad (75)$$

If $\pi = 0$ and $\tau = 0$, then $\lambda_3 = 0$. Combination of (71) and (72) then yields

$$\lambda_1 = \frac{\alpha}{1 - \alpha}.$$

In this case,

$$\lambda_2 = \frac{-\xi}{1 - \alpha} + \lambda_1.$$

Since $\lambda_2 \geq 0$, when $\alpha \geq \xi$, this is then a solution.

If $\pi = 0$ and $\tau > 0$, then $\lambda_2 = \lambda_3 = 0$. Hence, from (71),

$$\lambda_1 = \frac{\xi}{1 - \alpha + \tau\xi},$$

which is satisfied for $\tau > 0$. From (72),

$$\frac{\xi}{1 - \alpha + \tau\xi} = \frac{\alpha}{1 - \alpha} \frac{1}{1 - \tau},$$

which is satisfied for $\tau = (1 - \alpha)(1 - \frac{\alpha}{\xi})$. As $\tau > 0$, for this to be a solution $\alpha < \xi$.

If $\pi > 0$ and $\tau > 0$, then $\lambda_1 = \lambda_3 = 0$. Since,

$$\lambda_2 = \frac{-\xi}{1 - \alpha + (\tau - \pi)\xi},$$

for this to be a solution, $\lambda_2 > 0$. This requires $\pi > \tau$, which contradicts $\pi \leq \tau$.

We conclude that there are two solutions of the Kuhn-Tucker conditions:

$(\pi, \tau, \lambda_1, \lambda_2, \lambda_3) = (0, 0, \frac{\alpha}{1 - \alpha}, \frac{\alpha - \xi}{1 - \alpha}, 0)$ if $\alpha \geq \xi$, and $(0, (1 - \alpha)(1 - \frac{\alpha}{\xi}), \frac{\xi}{1 - \alpha + \tau\xi}, 0, 0)$ if $\alpha < \xi$. When $\pi = 0$ and $\tau = (1 - \alpha)(1 - \frac{\alpha}{\xi})$, $\frac{\partial \gamma^O}{\partial \xi} = \frac{\rho f(\cdot)}{1 + \rho + \xi - \alpha} (\frac{\alpha}{1 - \alpha} + \frac{\xi}{\alpha + \xi} - \frac{\rho\xi}{1 + \rho + \xi - \alpha})$. Hence, when $\frac{\alpha}{1 - \alpha} + \frac{\xi}{\alpha + \xi} < \frac{\rho\xi}{1 + \rho + \xi - \alpha}$, $\frac{\partial \gamma^O}{\partial \xi} < 0$.

Now, by continuity, this also holds for “sufficiently small” positive β 's. \square

A.6 Proof of Lemma 4

We consider the problem

$$\max_{\tau} \bar{V}_t(c_{1t}, c_{2t}, \gamma) \text{ subject to } \tau \geq 0 \text{ and } \tau < 1$$

given $\pi = \tau$, and where $\bar{V}_t(c_{1t}, c_{2t}, \gamma)$ is given by (36) in the main text with insertion of (26), (27) and (25) when the economy is constrained to be without bequests, and with insertion of (31), (32), and (29), when the economy is constrained to be with bequests. \bar{V}_t is twice differentiable and concave and the restrictions are all linear. The Kuhn-Tucker conditions are thus both necessary and sufficient. The Lagrangian is

$$\mathcal{L} = \bar{V}_t + \lambda_1 \tau - \lambda_2(\tau - 1).$$

The three Kuhn-Tucker conditions are

$$\frac{\partial \bar{V}_t}{\partial \tau} + \lambda_1 - \lambda_2 = 0 \tag{76}$$

$$\lambda_1 \geq 0, \tau \geq 0, \lambda_1 \tau = 0 \tag{77}$$

$$\lambda_2 \geq 0, \tau < 1, \lambda_2(\tau - 1) = 0 \tag{78}$$

where

$$\frac{\partial \bar{V}_t}{\partial \tau} = \frac{1}{1 - \beta} \left[\frac{1}{c_{1t}} \frac{\partial c_{1t}}{\partial \tau} + \frac{\rho}{c_{2t}} \frac{\partial c_{2t}}{\partial \tau} + \left(\frac{\beta + \rho}{1 - \beta} \right) \frac{1}{1 + \gamma(\tau, \cdot)} \frac{\partial \gamma(\tau, \cdot)}{\partial \tau} \right]. \tag{79}$$

Under assumption 1, $\pi = \tau$, on a balanced growth path without bequests,

$$\frac{1}{c_{1t}^O} \frac{\partial c_{1t}^O}{\partial \tau} = \frac{\xi}{\alpha + \tau \xi} - \frac{\alpha}{(1 - \alpha)(1 - \tau)}, \tag{80}$$

and

$$\frac{1}{c_{2t}^O} \frac{\partial c_{2t}^O}{\partial \tau} = - \frac{\alpha}{(1 - \alpha)(1 - \tau)}, \tag{81}$$

and

$$\frac{1}{1 + \gamma^O(\tau, \cdot)} \frac{\partial \gamma^O(\tau, \cdot)}{\partial \tau} = \frac{\xi}{\alpha + \tau \xi} - \frac{\alpha}{(1 - \alpha)(1 - \tau)}. \tag{82}$$

Substituting (80), (81), and (82) into (79), we get

$$\frac{\partial \bar{V}_t^O}{\partial \tau} = \frac{1}{1 - \beta} \left[\left(\frac{1 + \rho}{1 - \beta} \right) \frac{\xi}{\alpha + \tau \xi} - \left(\rho + \frac{1 + \rho}{1 - \beta} \right) \frac{\alpha}{(1 - \alpha)(1 - \tau)} \right].$$

By the Kuhn-Tucker conditions, if $\tau = 0$, then $\lambda_2 = 0$, thus by (76),

$$\lambda_1 = -\frac{\partial \bar{V}_t^O}{\partial \tau}.$$

Since $\lambda_1 \geq 0$, $\left(\rho + \frac{1+\rho}{1-\beta}\right) \frac{\alpha}{1-\alpha} \geq \left(\frac{1+\rho}{1-\beta}\right) \frac{\xi}{\alpha}$ for this to be satisfied. Hence, $\alpha \geq \bar{\chi}^O \xi$ where $\bar{\chi}^O \equiv \frac{1+\rho}{\rho(1-\beta)+1+\rho} \frac{1-\alpha}{\alpha} (> 0)$ for $\tau = 0$ to be a solution.

If $\tau > 0$, then $\lambda_1 = \lambda_2 = 0$, thus by (76),

$$\lambda_1 = -\frac{\partial \bar{V}_t^O}{\partial \tau} = 0.$$

Hence, $\left(\rho + \frac{1+\rho}{1-\beta}\right) \frac{\alpha}{(1-\alpha)(1-\tau)} = \left(\frac{1+\rho}{1-\beta}\right) \frac{\xi}{\alpha + \tau \xi}$, which implies $\tau = \frac{\xi \bar{\chi}^O - \alpha}{\xi(1 + \bar{\chi}^O)}$, which is then a solution when $\xi \bar{\chi}^O > \alpha$.

We conclude that there are two solutions of the Kuhn-Tucker conditions:

$$(\bar{\tau}^O, \lambda_1, \lambda_2) = (0, -\frac{\partial \bar{V}_t^O}{\partial \tau}, 0) \text{ if } \alpha \geq \bar{\chi}^O \xi \text{ and } (\frac{\xi \bar{\chi}^O - \alpha}{\xi(1 + \bar{\chi}^O)}, 0, 0) \text{ if } \xi \bar{\chi}^O > \alpha.$$

On a balanced growth path with positive bequests,

$$\frac{1}{c_{1t}^D} \frac{\partial c_{1t}^D}{\partial \tau} = \frac{\xi}{1 + \tau \xi - \beta(1 - \alpha)} - \frac{\alpha}{(1 - \alpha)(1 - \tau)}, \quad (83)$$

and

$$\frac{1}{c_{2t}^D} \frac{\partial c_{2t}^D}{\partial \tau} = \frac{\xi}{1 + \tau \xi - \beta(1 - \alpha)} - \frac{\alpha}{(1 - \alpha)(1 - \tau)}, \quad (84)$$

and

$$\frac{1}{1 + \gamma^D(\tau, \cdot)} \frac{\partial \gamma^D(\tau, \cdot)}{\partial \tau} = -\frac{\alpha}{(1 - \alpha)(1 - \tau)}. \quad (85)$$

Substituting (83), (84), and (85) into (79), we find

$$\frac{\partial \bar{V}_t^D}{\partial \tau} = \frac{1}{1 - \beta} \left\{ \left[\frac{\xi}{1 + \tau \xi - \beta(1 - \alpha)} \right] (1 + \rho) - \left(\rho + \frac{1 + \rho}{1 - \beta} \right) \frac{\alpha}{(1 - \alpha)(1 - \tau)} \right\}.$$

By the Kuhn-Tucker conditions, if $\tau = 0$ then $\lambda_2 = 0$. By (76), then

$$\lambda_1 = -\frac{\partial \bar{V}_t^D}{\partial \tau}.$$

Since $\lambda_1 \geq 0$, $\left(\rho + \frac{1+\rho}{1-\beta}\right) \frac{\alpha}{(1-\alpha)} \geq \left[\frac{\xi}{1-\beta(1-\alpha)}\right] (1 + \rho)$ for this to be a solution. Hence, $1 - \beta(1 - \alpha) \geq \bar{\chi}^D \xi$ where $\bar{\chi}^D \equiv \frac{(1+\rho)(1-\beta)}{\rho(1-\beta)+1+\rho} \frac{1-\alpha}{\alpha} = (1 - \beta) \bar{\chi}^O (> 0)$ is a solution.

If $\tau > 0$, then $\lambda_1 = \lambda_2 = 0$. By (76), then

$$\lambda_1 = -\frac{\partial \bar{V}_t^D}{\partial \tau} = 0.$$

Hence, $\left[\frac{\xi}{1+\tau\xi-\beta(1-\alpha)} \right] (1+\rho) = \left(\rho + \frac{1+\rho}{1-\beta} \right) \frac{\alpha}{(1-\alpha)(1-\tau)}$ which implies $\tau = \frac{\xi\bar{\chi}^D - [1-\beta(1-\alpha)]}{\xi(1+\bar{\chi}^D)}$. Since $\tau > 0$, for this to be a solution, $\xi\bar{\chi}^D > [1 - \beta(1 - \alpha)]$.

We conclude that there are two solutions of the Kuhn-Tucker conditions: $(\bar{\tau}^D, \lambda_1, \lambda_2) = (0, -\frac{\partial \bar{V}_t^D}{\partial \tau}, 0)$ if $1 - \beta(1 - \alpha) \geq \bar{\chi}^D \xi$ and $(\frac{\xi\bar{\chi}^D - [1-\beta(1-\alpha)]}{\xi(1+\bar{\chi}^D)}, 0, 0)$ if $\xi\bar{\chi}^D > [1 - \beta(1 - \alpha)]$. \square

A.7 Proof of Lemma 5

We consider the problem

$$\max_{\tau} \underline{V}_t(c_{1t}, c_{2t}, \gamma) \text{ subject to } \tau \geq 0 \text{ and } \tau < 1$$

given $\pi = \tau$, and where $\underline{V}_t(c_{1t}, c_{2t}, \gamma)$ is given by (38) in the main text with insertion of (26), (27) and (25) when the economy is constrained to be without bequests, and with insertion of (31), (32), and (29), when the economy is constrained to be with bequests. \underline{V}_t is twice differentiable and concave and the restrictions are all linear. The Kuhn-Tucker conditions are thus both necessary and sufficient. The Lagrangian is

$$\mathcal{L} = \underline{V}_t + \lambda_1 \tau - \lambda_2 (\tau - 1).$$

The three Kuhn-Tucker conditions are

$$\frac{\partial \underline{V}_t}{\partial \tau} + \lambda_1 - \lambda_2 = 0 \tag{86}$$

$$\lambda_1 \geq 0, \tau \geq 0, \lambda_1 \tau = 0 \tag{87}$$

$$\lambda_2 \geq 0, \tau < 1, \lambda_2 (\tau - 1) = 0 \tag{88}$$

where

$$\frac{\partial \underline{V}_t}{\partial \tau} = \left(1 + \frac{\beta\rho}{1-\beta} \right) \frac{1}{c_{2t}} \frac{\partial c_{2t}}{\partial \tau} + \frac{\beta}{1-\beta} \left[\frac{1}{c_{1t}} \frac{\partial c_{1t}}{\partial \tau} + \left(\frac{\beta+\rho}{1-\beta} \right) \frac{\frac{\partial \gamma(\tau, \cdot)}{\partial \tau}}{1+\gamma(\tau, \cdot)} \right]. \tag{89}$$

Substituting (80), (81), and (82) from the proof of Lemma 4 into (89), we find

$$\frac{\partial \underline{V}_t^O}{\partial \tau} = \frac{\beta}{1-\beta} \left[\left(\frac{1+\beta\rho}{\beta} + \frac{\beta+\rho}{1-\beta} \right) \frac{-\alpha}{(1-\alpha)(1-\tau)} + \frac{1+\rho}{1-\beta} \frac{\xi}{\alpha + \tau\xi} \right].$$

By the Kuhn-Tucker conditions, we have that if $\tau = 0$, then $\lambda_2 = 0$. By (86), then

$$\lambda_1 = -\frac{\partial \underline{V}_t^O}{\partial \tau}.$$

Since $\lambda_1 \geq 0$, $\left[1 + \frac{\beta(\rho + \frac{1+\rho}{1-\beta})}{1-\beta}\right] \frac{\alpha}{1-\alpha} \geq \frac{\beta}{1-\beta} \left(\frac{1+\rho}{1-\beta}\right) \frac{\xi}{\alpha}$ for this to be satisfied. Hence, $\alpha \geq \xi \underline{\chi}^O$, where $\underline{\chi}^O \equiv \frac{1+\rho}{\frac{(1-\beta)^2}{\beta} + \rho(1-\beta) + 1 + \rho} \frac{1-\alpha}{\alpha} (> 0)$, for this to be a solution.

If $\tau > 0$, then $\lambda_1 = \lambda_2 = 0$. By (86) first condition then

$$\lambda_1 = -\frac{\partial V_t^O}{\partial \tau} = 0.$$

Thus, $\left[1 + \frac{\beta(\rho + \frac{1+\rho}{1-\beta})}{1-\beta}\right] \frac{\alpha}{(1-\alpha)(1-\tau)} = \frac{\beta}{1-\beta} \left(\frac{1+\rho}{1-\beta}\right) \frac{\xi}{\alpha + \tau \xi}$, which implies $\tau = \frac{\xi \underline{\chi}^O - \alpha}{\xi(1 + \underline{\chi}^O)}$. Since $\tau > 0$, for this to be a solution, $\xi \underline{\chi}^O > \alpha$.

We conclude that there are two solutions of the Kuhn-Tucker conditions:

$$(\underline{\tau}^O, \lambda_1, \lambda_2) = (0, -\frac{\partial V_t^O}{\partial \tau}, 0) \text{ if } \alpha \geq \xi \underline{\chi}^O \text{ and } (\frac{\xi \underline{\chi}^O - \alpha}{\xi(1 + \underline{\chi}^O)}, 0, 0) \text{ if } \xi \underline{\chi}^O > \alpha.$$

When bequests are positive, by use of (83), (84), and (85) from the proof of Lemma 4, (89) is

$$\frac{\partial V_t^D}{\partial \tau} = \frac{1}{1-\beta} \left\{ (1 + \beta\rho) \frac{\xi}{1 + \tau\xi - \beta(1-\alpha)} - \left[1 + \beta\rho + \beta \left(\frac{\beta + \rho}{1-\beta}\right)\right] \frac{\alpha}{(1-\alpha)(1-\tau)} \right\}.$$

By the Kuhn Tucker conditions, if $\tau = 0$, then $\lambda_2 = 0$, and then

$$\lambda_1 = -\frac{\partial V_t^D}{\partial \tau}.$$

Since $\lambda_1 \geq 0$, $\left[(\beta\rho + 1 + \beta \left(\frac{\beta + \rho}{1-\beta}\right))\right] \frac{\alpha}{1-\alpha} \geq (1 + \beta\rho) \frac{\xi}{1-\beta(1-\alpha)}$ for this to be satisfied.

Hence, $1 - \beta(1 - \alpha) \geq \xi \underline{\chi}^D$ where $\underline{\chi}^D \equiv \frac{1 + \beta\rho}{\beta\rho + 1 + \beta \left(\frac{\beta + \rho}{1-\beta}\right)} \frac{1-\alpha}{\alpha} = \frac{\frac{1-\beta}{\beta}(1 + \beta\rho)}{\frac{(1-\beta)^2}{\beta} + \rho(1-\beta) + 1 + \rho} \frac{1-\alpha}{\alpha} (> 0)$ for this to be a solution.

If $\tau > 0$, then $\lambda_1 = \lambda_2 = 0$. By (86), then

$$\lambda_1 = -\frac{\partial V_t^D}{\partial \tau} = 0.$$

Thus, $\left[(\beta\rho + 1 + \beta \left(\frac{\beta + \rho}{1-\beta}\right))\right] \frac{\alpha}{(1-\alpha)(1-\tau)} = \frac{\xi(1 + \beta\rho)}{1 + \tau\xi - \beta(1-\alpha)}$, which implies $\tau = \frac{\xi \underline{\chi}^D - [1 - \beta(1 - \alpha)]}{\xi(1 + \underline{\chi}^D)}$.

Since $\tau > 0$, for this to be a solution, $\xi \underline{\chi}^D > [1 - \beta(1 - \alpha)]$.

We conclude that there are two solutions of the Kuhn-Tucker conditions:

$$(\underline{\tau}^D, \lambda_1, \lambda_2) = (0, -\frac{\partial V_t^D}{\partial \tau}, 0) \text{ if } 1 - \beta(1 - \alpha) \geq \xi \underline{\chi}^D \text{ and } (\frac{\xi \underline{\chi}^D - [1 - \beta(1 - \alpha)]}{\xi(1 + \underline{\chi}^D)}, 0, 0) \text{ if } \xi \underline{\chi}^D > [1 - \beta(1 - \alpha)]. \quad \square$$

A.8 Proof of Proposition 7

Bequests may be absent or present. Let $\bar{\gamma}^O$ denote the growth rate under a young spending policy when the economy is without bequests, then

$$\bar{\gamma}^O = \bar{\beta}^*(1 - \alpha)\bar{f}^O - 1 \equiv \bar{\gamma}^O(\bar{\tau}^O, \xi),$$

where $\bar{\beta}^* \equiv \beta^*(\bar{\tau}^O, \xi) = \frac{\rho(\alpha + \bar{\tau}^O \xi)}{(1 + \rho)(1 - \alpha)}$ and $\bar{f}^O \equiv f(\bar{\tau}^O, \xi)$, and let $\underline{\gamma}^O$ denote the growth rate under an old spending policy when the economy is without bequests, then

$$\underline{\gamma}^O = \underline{\beta}^*(1 - \alpha)\underline{f}^O - 1 \equiv \underline{\gamma}^O(\underline{\tau}^O, \xi),$$

where $\underline{\beta}^* \equiv \beta^*(\underline{\tau}^O, \xi) = \frac{\rho(\alpha + \underline{\tau}^O \xi)}{(1 + \rho)(1 - \alpha)}$ and $\underline{f}^O \equiv f(\underline{\tau}^O, \xi)$. Under both policies, direct transfers from the government may be zero or positive. We treat young and old policy in turn. Young policy (as given in lemma 4): When $\bar{\tau}^O = 0$, then

$$\frac{\partial \bar{\gamma}^O(\cdot)}{\partial \xi} = (1 - \alpha) \left[\frac{\rho \alpha}{1 + \rho} \frac{\partial \bar{f}^O}{\partial \xi} \right] > 0;$$

when, $\bar{\tau}^O = \frac{\xi \bar{\chi}^O - \alpha}{\xi(1 + \bar{\chi}^O)}$, then

$$\frac{d \bar{\gamma}^O(\cdot)}{d \xi} = (1 - \alpha) \left[\frac{\partial \bar{\beta}^*}{\partial \bar{\tau}^O} \frac{d \bar{\tau}^O}{d \xi} \bar{f}^O + \bar{\beta}^* \frac{\partial \bar{f}^O}{\partial \bar{\tau}^O} \frac{d \bar{\tau}^O}{d \xi} \right].$$

Since $\frac{\partial \bar{\beta}^*}{\partial \bar{\tau}^O} \frac{d \bar{\tau}^O}{d \xi} > 0$ and $\frac{\partial \bar{f}^O}{\partial \bar{\tau}^O} \frac{d \bar{\tau}^O}{d \xi} > 0$, we have that $\frac{d \bar{\gamma}^O(\cdot)}{d \xi} > 0$. Old policy (as given in lemma 5): When $\underline{\tau}^O = 0$, then

$$\frac{\partial \underline{\gamma}^O(\cdot)}{\partial \xi} = (1 - \alpha) \left[\frac{\rho \alpha}{1 + \rho} \frac{\partial \underline{f}^O}{\partial \xi} \right] > 0;$$

when, $\underline{\tau}^O = \frac{\xi \underline{\chi}^O - \alpha}{\xi(1 + \underline{\chi}^O)}$, then

$$\frac{d \underline{\gamma}^O(\cdot)}{d \xi} = (1 - \alpha) \left[\frac{\partial \underline{\beta}^*}{\partial \underline{\tau}^O} \frac{d \underline{\tau}^O}{d \xi} \underline{f}^O + \underline{\beta}^* \frac{\partial \underline{f}^O}{\partial \underline{\tau}^O} \frac{d \underline{\tau}^O}{d \xi} \right].$$

Since $\frac{\partial \underline{\beta}^*}{\partial \underline{\tau}^O} \frac{d \underline{\tau}^O}{d \xi} > 0$ and $\frac{\partial \underline{f}^O}{\partial \underline{\tau}^O} \frac{d \underline{\tau}^O}{d \xi} > 0$, we have that $\frac{d \underline{\gamma}^O(\cdot)}{d \xi} > 0$.

Let $\bar{\gamma}^D$ denote the growth rate under a young spending policy when the economy is dynastic, thus

$$\bar{\gamma}^D = \beta(1 - \alpha)\bar{f}^D - 1 \equiv \bar{\gamma}^D(\bar{\tau}^D, \xi),$$

where $\bar{f}^D \equiv f(\bar{\tau}^D, \xi)$. Likewise, let $\underline{\gamma}^D$ denote the growth rate under an old spending policy when the economy is dynastic, then

$$\underline{\gamma}^D = \beta(1 - \alpha)\underline{f}^D - 1 \equiv \underline{\gamma}^D(\underline{\tau}^D, \xi),$$

where $\underline{f}^D \equiv f(\underline{\tau}^D, \xi)$. Again, under both policies, direct transfers from the government may be zero or positive. We treat young and old policy in turn. Young policy (as given in lemma 4): When $\bar{\tau}^D = 0$, then

$$\frac{\partial \bar{\gamma}^D(\cdot)}{\partial \xi} = \beta(1 - \alpha) \frac{\partial \bar{f}^D}{\partial \xi} > 0,$$

and when $\bar{\tau}^D = \frac{\xi \bar{\chi}^D - [1 - \beta(1 - \alpha)]}{\xi(1 + \bar{\chi}^D)}$, then

$$\frac{\partial \bar{\gamma}^D(\cdot)}{\partial \xi} = \beta(1 - \alpha) \frac{\partial \bar{f}^D}{\partial \bar{\tau}^D} \frac{d\bar{\tau}^D}{d\xi} > 0.$$

Old policy (as given in lemma 5): When $\underline{\tau}^D = 0$ then

$$\frac{\partial \underline{\gamma}^D(\cdot)}{\partial \xi} = \beta(1 - \alpha) \frac{\partial \underline{f}^D}{\partial \xi} > 0,$$

and when $\underline{\tau}^D = \frac{\xi \underline{\chi}^D - [1 - \beta(1 - \alpha)]}{\xi(1 + \underline{\chi}^D)}$, then

$$\frac{\partial \underline{\gamma}^D(\cdot)}{\partial \xi} = \beta(1 - \alpha) \frac{\partial \underline{f}^D}{\partial \underline{\tau}^D} \frac{d\underline{\tau}^D}{d\xi} > 0.$$

Thus, there is no resource curse under young or old policies when the growth regime remains unaltered. \square

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CHAPTER 4

Labor Mobility, Household Production, and the Dutch Disease

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Abstract

This paper studies a model of Dutch disease with learning by doing and household production. Only women work in the households. We compare economies with mobile labor and economies with gender specific sectors. In the latter economy, in addition to working in the household, women work in either the traded or the non-traded sector, and men allocate all their labor to the sector not occupied by women. The effect of enhanced natural resource abundance on factor allocation, the real exchange rate, wage rates, production, and growth are worked out for each case. Our analysis suggests that labor mobility and differences in how gender is grouped across sectors play a role in how natural resource abundance impacts economic performance.

Key Words: Dutch Disease, Endogenous Growth, Household Production, Segmented Labor Markets, Gender Wage Differentials

JEL Classification Codes: F35, F43, J22, J62, O41

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1 Introduction

Despite substantial efforts to reveal empirically the nature of how natural resource abundance interacts with economic development, it appears that no definite answers can be given to whether such abundance is a blessing or a curse.¹ Earlier literature on the Dutch disease² depicts a negative relationship between resource abundance and productivity levels (see in particular van Wijnbergen 1984; Krugman 1987; Sachs and Warner 1995; and Gylfason et al. 1997 in the learning by doing context) and economic growth (Sachs and Warner 1995; and Gylfason et al. 1997). In contrast, Torvik (2001) proposes a Dutch disease model in which variation in sectoral learning by doing effects and spillover rates explains variation in how natural resources impact sectoral productivity. In this model, natural resources have no impact upon the long-term growth rate.

Generally, in these models labor moves flexibly between the traded and the non-traded sector, and the labor supply is exogenously given and constant. Behind these approximations lies an assumption about perfect labor mobility and about inelastic labor supply. While these assumptions may apply to some economies, they clearly seem unrealistic for others. They ignore the possibility that societal structures in the labor market matter for how an economy responds to changes in natural resource abundance, which is precisely what the Dutch disease models seek to analyze. Nevertheless, aspects of labor mobility and labor supply are almost³ completely neglected in the existing Dutch disease literature.

We pay special attention to two circumstances which motivate how this issue can be addressed. The first circumstance concerns gender-grouping of the labor market.

¹The resource curse hypothesis receives support by a large body of empirical literature (Auty 1993, 2001; Sachs and Warner 1995, 1999, 2001 among others). Nevertheless, the notion of an unconditional curse is also questioned empirically (Larsen 2005; Sala-i-Martin et al. 2004; Stijns 2005; Ng 2006). See Frederiksen (2007) for a survey of the recent empirical literature.

²The precise meaning of Dutch disease has evolved over time (consult Stevens (2003) for a review). Our paper belongs to the strand of literature that relates Dutch disease to learning by doing effects on productivity and growth.

³We know of two exceptions; both neoclassical models. Hoel (1981) analyzes a short run Dutch disease model, where labor is immobile. Hsieh et al. (1998) examine endogenous labor-leisure choices within a Dutch disease model.

Gender-based occupational segregation, which has been shown to be a worldwide phenomenon, describes the situation in which labor markets are divided on the basis of gender (Anker 1998). Occupational segregation can be explained by social and cultural barriers that leads to labor market immobility, and, consequently, to a reduction in the economy's ability to adjust to change. Since it is precisely the economy's ability to adjust to change - in the form of a increased resource abundance - which leads to the Dutch disease, occupational segregation presumably matters for predicting Dutch disease symptoms.

The second circumstance concerns household production. Household production supports the lives of most families; yet a person engaged in production for household use is not usually regarded as belonging to the labor force. Endogenous labor supply decisions, however, also influence how the economy adjusts to changes in resource abundance.

Therefore, we add a household sector to an economy, which is otherwise described by a Dutch disease model with learning by doing effects. We consider labor in the household a heterogeneous factor in production in that male labor is not productive. With respect to production in the two other sectors, the traded and the non-traded sector, we consider first labor as a homogenous factor of production, but barriers, such as stigma and customs, force men and women to work in separate sectors. Second, we consider an economy in which labor is completely mobile between the traded and the non-traded sector. In this scenario, the main departure from Torvik (2001) is the endogeneity of the female labor supply.

Our analysis demonstrates that labor market structures play a critical role in whether natural resources are a blessing or a curse; i.e., in the context of this paper, for production and growth. Slower economic growth rates in natural resource abundant economies are explained by a movement of female labor into the household sector which does not contribute to overall economic growth. As we also show, whether women decrease their labor supply in response to increased natural resource abundance, in turn, depends on the gender-grouping of the labor market.

The paper is organized as follows. Next, we provide background information

to support our analysis of the labor market. Section 3 presents the model, and equilibrium outcomes are explained in section 4. Section 5 presents a resource impact analysis. In particular, we analyze the link between labor market structure and the Dutch disease. Section 6 provides concluding remarks.

2 Background

Men's and women's labor market patterns diverge. Among other things, this divergence is manifested as gender-differences in occupations: "Occupational segregation by sex⁴ is extensive in every region, at all economic development levels, under all political systems, and in diverse religious, social and cultural environments. It is one of the most important and enduring aspects of labour markets around the world" (Anker 1997, 315).

Explanations and theories of occupational segregation are numerous.⁵ Anker (1998) distinguishes three categories: neoclassical, segmentation, and non-economic theories. Neoclassical theories typically explain occupational segregation by gender-differences in preferences, or in human capital. If women are less educated than men, for instance because women spend more time in the household, they will work in occupations that requires lower levels of education. Segmentation theories, on the other hand, argue that so-called barriers, which could be institutional, exist between segments of the economy. The idea is that each sector may function according to neoclassical theory, but barriers prevent interaction between sectors. Typically, one of the sectors is the well paid, "primary," or male dominated sector, whereas the other sector is the less attractive, "secondary," or female dominated, sector. Finally, non-economic explanations involve social norms and cultural restrictions. A classical example is *purdah*, which forbids women in some Islamic cultures to interact with male strangers in public (Anker 1998). Goldin (1995) argues that low-income societies stigmatize the husbands of women who perform paid work.

⁴Often, the literature distinguishes between "sex" and "gender." The term "sex" refers to biology, and the term "gender" to differences that are learned on the basis of cultural or social norms. The current paper, however, uses the terms "sex" and "gender" interchangeably.

⁵See, e.g., Leontaridi (1998) for a review of the literature.

The extent of gender-segregation in occupations varies from region to region. Sanday (1981, 80) notes that: “Sexual separation is so extreme in some societies that almost all work activities are defined as either male or female, with the result that the sexes form sexual ghettos.” At the same time, Sanday finds considerable diversity in the cultural patterning of work. Also Boserup (1970) documents wide variations across Africa, Asia, and Latin America in the representation of women in agriculture, trade, and administration. Tasks considered male in one society are often allocated to women in others.

There are several ways to measure gender-based occupational segregation. Anker (1998) presents two,⁶ among others, measures: the *index of dissimilarity* (ID) and *the representation ratio for women*. The ID measure is the most commonly used, but also criticized, index for measuring gender segregation of labor markets. It measures the sum over all occupations of the absolute differences between the proportion of all females and all males in each occupation divided by two, and hence it ranges from zero to one. The higher the ID, the higher the gender-based occupational segregation. Table 1 presents the ID in five regions of the world.

Table 1 Regional index of dissimilarity (ID)

	Region ^a				
	OECD	Middle East and North Africa	Asia/Pacific	Other Developing	Transition Economies
ID	0.600	0.672	0.492	0.629	0.593

Source: Anker (1998).

^a In all, 41 countries are included in the data.

We observe a variation in the degree of gender segregation across regions. Gender segregation is highest in the Middle East and North Africa region, and lowest in the Asia/Pacific region. We also note that the OECD region has considerable segregation. The pattern of gender segregation in table 1 is in conformity with women’s representation ratios across six occupational groups, all non-agricultural, which are

⁶We refer to Anker (1998, ch. 5) for a thorough and technical explanation of the different measures.

illustrated in table 2. The representation ratio is the percentage female in an occupational group divided by the average percentage female for the non-agricultural labor force⁷ as a whole. A value greater than one implies that women are overrepresented, and a value less than one implies that women are underrepresented, relative to their overall share of the non-agricultural labor force.

Table 2 Representation Ratios for Women for Six Occupational Groups

Region ^a	Occupational Group					
	Professional and technical	Admin. and managerial	Clerical	Sales	Services	Production
OECD	1.17	0.51	1.61	1.24	1.51	0.37
Middle East and North Africa	2.43	0.46	1.85	0.28	1.25	0.33
Asia/Pacific	1.35	0.34	0.95	1.02	1.42	0.74
Latin America and Caribbean	1.21	0.58	1.37	1.25	1.53	0.43
Africa	1.15	0.39	1.31	1.47	1.13	0.51

Source: Anker (1998).

^a In all, 56 countries are included in the data.

Table 2 reveals variation across regions in the representation of women. In addition, which is not shown in the table, there is also great variation within regions (Anker 1998). In general, however, there are two occupational groups in which women are underrepresented: administrative and managerial occupations and production. The administrative and managerial occupational group is a small group and employs roughly four percent of the labor force. In contrast, production is a large occupational group and employs about 33-48 percent of the labor force. As production sectors are typically the traded sectors, this indicates that women are generally underrepresented in trade. As shown in table 2, women's underrepresentation in production is smallest in the Asia/Pacific region. Women have therefore most likely contributed to the development of this region, which has been ascribed largely to exports (UNIDO 1994).

⁷In Anker's (1998) representation ratio estimates, agricultural occupations are excluded from the data. The reason is methodological problems of measuring correctly and consistently agricultural employment, as a large share of agricultural employment is incorporated in household work; especially, in developing countries.

Within the two male dominated occupational groups: administrative and managerial occupations and production, men typically hold jobs as government administrators and various types of construction workers.

Not surprisingly, women are overrepresented in the traditional female occupations such as services, clerical, and sales, with the exception of the Middle East and North Africa region, in which women are strongly underrepresented in sales. Women's underrepresentation in sales in this region may be explained by the above mentioned tradition of *purdah*. Women are generally also overrepresented in the professional and technical group. This can be ascribed to their larger representation in jobs such as teachers and nurses.

Another aspect of the differences in men's and women's labor market patterns relates to the household sector in that households, worldwide, are operated mainly by female labor. In developing countries, despite variations from rural to urban households, as some household work, or subsistence activities, which can be performed in rural areas cannot be carried out in urban surroundings, women use a large share of their labor endowments in the household (Boserup 1970). Newman (2002) finds that in Ecuador, men spend on average 62 minutes per day in the household, whereas women spend as much as 327 minutes. In Pakistan, Fafchamps and Quisumbing (2003) find that women do 80-90 percent of all household chores. Also women in developed countries use a substantial part of their labor resources in the household. Freeman and Schettkat (2005) find, among seven developed countries,⁸ that women, on a daily work day, spend on average 203 minutes, whereas men spend only 93 minutes, in the home.

In the context of a Dutch disease model, gender-differences in labor market patterns form an additional, a societal, dimension. As pointed out in, e.g., Torvik (2001) and Isham et al. (2005), there is great variation across nations in what sectors produce exported, traded goods, and what sectors produce domestic, non-traded, goods. For instance, some countries may export manufactured goods, whereas other

⁸Freeman and Schettkat (2005) study Canada, Netherlands, Norway, UK, US, Italy, and Austria.

countries export agricultural goods. Based on the labor market patterns presented above, it is therefore likely, that, besides this type of variation, there is also variation across countries in whether traded and non-traded sectors are “male” or “female” occupations.⁹

Thus, in order to study how different combinations of gender and sectors, or what we could refer to as societal structures, effect the economy’s adjustment pattern to a change in natural resource abundance, this paper provides both an analysis of a gender segmented labor market, and of a labor market in which traded and non-traded sectors are divided equally among men and women. In each case, however, only women work in the household.

3 The Model

We use a non-overlapping generations model with perfect competition. The economy consists of three sectors. Sector 1 is a non-traded sector, sector 2 is a traded sector, and sector 3 is a household sector. We refer to the traded and the non-traded sectors as the formal sectors since output is sold and purchased in the market place. Output from the household sector is completely consumed within the household, in which it is produced. All sectors employ labor supplied by household members, and, specifically, the household sector uses only female labor.

Households are formed by two individuals, a woman and a man. Both live for one period, and both have an endowment of $L > 0$ units of labor. The number of households remains constant, households are identical, and we normalize the number of households to equal one.

3.1 Traded and Non-traded Production

Also producers within each of the traded and the non-traded sectors are identical. For the representative producer, production occurs with labor, l_t , and a fixed factor

⁹Of course, this hypothesis would be strengthened considerably by a detailed study of separate countries. For now, this is beyond the scope of this paper and left for future investigation. Some preliminary results in this direction can be found in Ross (2006).

as input. Production in the specific factors model has constant returns to scale,¹⁰ and we consider one firm within each sector. Growth is fuelled by learning by doing and evolves over time as a by-product of production. Let x_{st} denote output in the $s = (1, 2)$ sector at time t ; thus,

$$x_{1t} = H_{1t}l_{1t}^\alpha, \quad (1)$$

$$x_{2t} = H_{2t}l_{2t}^\beta, \quad (2)$$

where $H_{s0} > 0$, H_{st} is a positive productivity term, which can vary between the two sectors, and $0 < \alpha < 1$ and $0 < \beta < 1$ are the labor shares in production.

Earlier literature on the Dutch disease has traditionally attributed productivity growth to the traded sector only; e.g., van Wijnbergen (1984) and Krugman (1987). Sachs and Warner (1995) introduce perfect spillover of learning by doing to the non-traded sector. We follow Torvik's (2001) approach and assume that learning by doing is generated in all formal sectors, and that intersectoral spillovers are positive in all directions. Let g_{st} denote growth rates of productivity in the s sector; then,

$$\frac{\dot{H}_{1t}}{H_{1t}} = g_{1t} = l_{1t} + \delta l_{2t}, \quad (3)$$

$$\frac{\dot{H}_{2t}}{H_{2t}} = g_{2t} = \delta l_{1t} + l_{2t}, \quad (4)$$

where $0 \leq \delta \leq 1$ is the spillover rate between sectors.¹¹ To simplify matters, the spillover rate from the non-traded sector to the traded sector equals that from the traded sector to the non-traded sector.¹² As workers from each formal sector interact in other places than at the workplace, even in a situation when labor is intersectorally immobile, technology diffusion can still occur.

Using the traded good¹³ as *numeraire*, p_{1t} is the price of the non-traded good in terms of the traded good, i.e., the real exchange rate. The representative competitive producer within each sector employs factors in order to maximize profits,

¹⁰Specific factor models often assume that one sector uses capital specific to that sector, and another uses land, both fixed in supply, and that labor is mobile. See, e.g., Matsuyama (1992).

¹¹Thus, within sectors, this model suffers from the often criticized permanent growth effect of scale.

¹²Torvik (2001) contains a rigorous analysis of different spillover rates.

¹³The price of the traded good is given as a given (world market) price, whereas prices on the non-traded good and the household good are determined within the model.

π_{st} , and takes as given output and input prices. Under perfect competition, profit maximization leads to

$$\frac{\partial \pi_{1t}}{\partial l_{1t}} = p_{1t} \alpha \frac{x_{1t}}{l_{1t}} - w_{1t} = 0, \quad (5)$$

$$\frac{\partial \pi_{2t}}{\partial l_{2t}} = \beta \frac{x_{2t}}{l_{2t}} - w_{2t} = 0, \quad (6)$$

where w_{st} is the wage rate in sector $s = (1, 2)$. The firm's profits are maximized when the marginal product of labor equals the wage rate.

3.2 Natural Resources

The economy is endowed with natural resources. In every period t , the economy receives a return from the natural resource as an inflow, a revenue, R_t , which is given directly to the households. The revenue is a fixed fraction, $\xi \geq 0$, of the real income of man-made output in the formal sectors in terms of traded goods, y_t :

$$R_t = \xi y_t, \quad (7)$$

where $y_t = p_{1t}x_{1t} + x_{2t}$. We refer to ξ as to the natural resource abundance. The revenue, R_t , varies with changes in output in either formal sector, but the revenue output ratio remains constant. Using this specification, we model the natural resource revenues as if they arrive as manna from heaven. An alternative interpretation is to think of R_t as inflows of foreign aid.¹⁴

3.3 Households and Household Production

Production in the household sector differs from formal production in that it purely takes female labor as input. Furthermore, productivity is constant¹⁵ and does not interact with productivity in the formal sectors. Let x_{3t} denote output, so that

$$x_{3t} = l_{3t}^\gamma, \quad (8)$$

¹⁴Similar ways of modeling of either a natural resource or foreign aid inflow are found in Chatterjee et al. (2003), Lesink and White (2001), Papyrakis and Gerlagh (2004), and Torvik (2001).

¹⁵Fafchamps and Quisumbing (2003) find a constant reallocation of household chores among women, which implies that household chores are easy to learn. Put differently, it seems there is no learning by doing effect which increases productivity in the household.

where $0 < \gamma \leq 1$.

We assume that each family member has an equal weight in the family welfare function and identical preferences. In this case, we use a conventional unitary household model with household production. Preferences are defined over consumption of the non-traded good, c_{1t} ; consumption of the traded good, c_{2t} ; and consumption of the household good, z_t . For convenience, let the utility function, u , be given as

$$u(c_{1t}, c_{2t}, z_t) = \phi \ln(c_{1t}) + (1 - \phi) \ln(c_{2t}) + \mu \ln(z_t), \quad (9)$$

where $0 < \phi < 1$ and $\mu > 0$ are parameters. There are no savings or bequests in the economy, so household consumption equals household income at any period. Disposable household income is the sum of male and female earnings and the value of a natural resource revenue, R_t . Accordingly, the household maximizes utility given in (9) subject to

$$p_{1t}c_{1t} + c_{2t} = p_{1t}x_{1t} + x_{2t} + R_t, \quad (10)$$

$$p_{3t}z_t = p_{3t}x_{3t}, \quad (11)$$

$$l_t^f + l_{3t} = L, \text{ with } l_t^f \geq 0 \text{ and } l_{3t} \geq 0, \quad (12)$$

$$l_t^m = L, \quad (13)$$

by efficiently choosing c_{1t} , c_{2t} , and z_t , taking as given prices and the resource revenue, R_t . The shadow price of the household good relative to the price on the traded good is denoted p_{3t} , and labor shares, l_t^f and l_t^m , are the female and male labor supply to the formal sectors respectively. Eq. (10) says that the household uses disposable income for consumption of the traded and the non-traded good, and (11) says that the household consumes all the household good which is produced within the household. Eq. (12) is the female labor endowment constraint and (13) its male counterpart.

The first order conditions from the utility maximization problem are given as

$$\frac{\phi}{1-\phi} \frac{c_{2t}}{c_{1t}} = p_{1t}, \quad (14)$$

$$\frac{\mu}{1-\phi} \frac{c_{2t}}{z_t} = p_{3t}, \quad (15)$$

$$\frac{\mu}{\phi} \frac{c_{1t}}{z_t} = \frac{p_{3t}}{p_{1t}}, \quad (16)$$

$$\frac{w_t^f}{\gamma(L - l_t^f)^{\gamma-1}} = p_{3t}, \quad (17)$$

where w_t^f denotes the wage rate of female labor. Denoting profits in the sector in which women work as π_t^f , by (5) and (6), $\frac{\partial \pi_t^f}{\partial l_t^f} = w_t^f$.

The first three conditions, (14)-(16), are the standard conditions ensuring that the marginal rate of transformation between any two goods equals the marginal rate of substitution between the same two goods. Due to Cobb-Douglas preferences, budget shares are constant. The last condition, (17), says that the marginal value product of the labor in household production good equals the opportunity cost, the wage rate, in optimum.

4 Equilibrium

In equilibrium, firms earn zero marginal profits. Hence, from (5) and (6)

$$w_{1t}^* = p_{1t}^* \alpha H_{1t} l_{1t}^{*\alpha-1}, \quad (18)$$

$$w_{2t}^* = \beta H_{2t} l_{2t}^{*\beta-1}, \quad (19)$$

where a star denotes equilibrium levels.

The labor market clears for both male and female workers, which means

$$l_t^{m*} = L, \quad (20)$$

$$l_t^{f*} = L - l_{3t}^*, \quad (21)$$

as only women divide their labor between the household sector and a formal sector.

The non-traded good market clears: i.e., consumption equals supply:

$$c_{1t}^* = x_{1t}^*,$$

and consumption of the household good equals production of the household good;

$$z_t^* = x_{3t}^*.$$

Using the shadow price of the household good, the resource constraint is

$$p_{1t}^* c_{1t}^* + c_{2t}^* + p_{3t}^* z_t^* = (1 + \xi) y_t^* + p_{3t}^* x_{3t}^*, \quad (22)$$

as the traded good is the numeraire.

In order to evaluate income level effects, we also give

$$GDP_t^* = y_t^* + R_t^* = p_{1t}^* x_{1t}^* + x_{2t}^* + R_t^* = (1 + \xi)(p_{1t}^* x_{1t}^* + x_{2t}^*), \quad (23)$$

where y_t^* is man-made output, and the last equality follows from (7).

4.1 Characterizing Three Economies

We study three template economies, or scenarios, which we refer to as *Men in Trade (MiT)*, *Women in Trade (WiT)*, and *Mobile Labor (ML)* respectively. In the two former economies, the labor market is completely segmented by sex. Men inelastically supply all labor to one sector,¹⁶ whereas women face a trade-off between allocating labor to the household sector and a formal sector. In a *Mobile Labor* economy, male and female workers move freely between formal sectors.

In the following, we solve the model for each economy. As only the supply side of the model differs among the three labor market specifications, we begin by deriving the demand side.

From (22), the first order conditions from the household's utility maximization problem, (14)-(16), and the definition of y_t , the demand for the non-traded good can be presented as

$$p_{1t} = \frac{\phi(1 + \xi)}{1 - \phi(1 + \xi)} \frac{x_{2t}}{x_{1t}} = \frac{\phi(1 + \xi)}{1 - \phi(1 + \xi)} \frac{H_{2t} l_{2t}^\beta}{H_{1t} l_{1t}^\alpha}, \quad (24)$$

where the last equality follows from (1) and (2). Likewise, the demand for the household good can be found as

$$p_{3t} = \frac{\mu(1 + \xi)}{1 - \phi(1 + \xi)} \frac{x_{2t}}{x_{3t}} = \frac{\mu(1 + \xi)}{1 - \phi(1 + \xi)} \frac{H_{2t} l_{2t}^\beta}{l_{3t}^\gamma}, \quad (25)$$

¹⁶Thus, the sector in which men work is treated as an "all-factors-specific" sector.

where the last equality follows from (2) and (8). We combine (24) and (25), since this expression becomes useful later, to obtain

$$p_{1t} = \frac{\phi x_{3t}}{\mu x_{1t}} p_{3t} = \frac{\phi l_{3t}^\gamma}{\mu H_{1t} l_{1t}^\alpha} p_{3t}. \quad (26)$$

We notice a constant term in (24), (25), and (26). This term reflects that budget shares are constant. Moreover, in (24) and (25) the constant involves the term $1 + \xi$, which adjusts for that fact that a positive resource revenue inflow puts a wedge between consumption and production of the traded good. If the resource inflow is absent, the constant term in (24) and (25) is simply the relative budget shares given by the preferences.

Having laid out the demand side of the model, we now turn to the supply side for each scenario in order to characterize the equilibrium labor allocation.

4.1.1 Labor Allocation in the Men in Trade Economy

In a *MiT* economy, by (12) and (13), $l_t^f \equiv l_{1t}$, thus, $l_{1t} + l_{3t} = L$. Moreover, $l_t^m \equiv l_{2t}^* = L$ by definition. We use the labor allocation efficiency condition in (17) to derive the supply of the household good. By (18), since women work in the non-traded sector, (17) becomes:

$$p_{3t}^{MiT} = p_{1t}^{MiT} \frac{\alpha}{\gamma} H_{1t} (l_{1t})^{\alpha-1} (L - l_{1t})^{1-\gamma}. \quad (27)$$

Equating (26) and (27), the female labor supply in equilibrium is derived as

$$l_1^{MiT}(\alpha, \gamma, \phi, \mu)^* = \left(\frac{1}{\frac{\mu \gamma}{\phi \alpha} + 1} \right) L, \quad (28)$$

and, by the labor endowment constraint,

$$l_3^{MiT}(\alpha, \gamma, \phi, \mu)^* = \left(\frac{\frac{\mu \gamma}{\phi \alpha}}{\frac{\mu \gamma}{\phi \alpha} + 1} \right) L. \quad (29)$$

We observe that both the female labor allocation and the female labor supply are constant and independent of the resource abundance. Moreover, the higher the labor share in production within a sector, and the higher the budget share of its output, the greater the share of the labor endowment which is being allocated to that particular sector; i.e., $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial \alpha} < 0$, $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial \phi} < 0$, $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial \gamma} > 0$, and $\frac{\partial l_3^{MiT}(\cdot)^*}{\partial \mu} > 0$.

4.1.2 Labor Allocation in the Women in Trade Economy

In a *WiT* economy, women efficiently allocate their labor between the household and the traded sector. Therefore, by (12) and (13), $l_t^f \equiv l_{2t}$ and $l_{2t} + l_{3t} = L$. Men, by definition, inelastically supply labor to the non-traded sector; $l_t^m \equiv l_{1t}^* = L$.

Again we use the labor allocation efficiency condition in (17) to derive an expression for the supply of the household good. We apply (19) and find

$$p_{3t}^{WiT} = \frac{\beta}{\gamma} H_{2t} (l_{2t})^{\beta-1} (L - l_{2t})^{1-\gamma}. \quad (30)$$

By equating (25) and (30), the female labor supply to the traded sector in equilibrium is

$$l_2^{WiT}(\beta, \gamma, \phi, \mu, \xi)^* = \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L, \quad (31)$$

and, using the labor endowment constraint, the female labor share used in the household sector is

$$l_3^{WiT}(\beta, \gamma, \phi, \mu, \xi)^* = \left[\frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta}}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L. \quad (32)$$

To avoid corner solutions, we impose the following restriction on the natural resource abundance:

$$\xi < \frac{1-\phi}{\phi}.$$

When $\xi = \frac{1-\phi}{\phi}$, the inflow of resource revenues increase the demand for the non-traded good and the household good to an extent that all labor moves out of the traded sector until it shuts down. When $\xi > \frac{1-\phi}{\phi}$, there is no equilibrium as labor demand in the household sector exceeds the woman's labor endowment, L .

The woman's labor allocation depends on ξ , but it is constant for given levels of natural resource abundance. Like the *MiT* economy, women allocate more labor to the household the higher labor share in the home sector and the higher the budget share of its output, and reversely for the formal sector in which women work; i.e. $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \beta} < 0$, $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \phi} > 0$, $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \gamma} > 0$, and $\frac{\partial l_3^{WiT}(\cdot)^*}{\partial \mu} > 0$.

4.1.3 Labor Allocation in the Mobile Labor Economy

In a ML economy, the size of the labor force is the sum of female and male labor endowments minus female labor used in the household sector; i.e., $2L - l_{3t}$. Of this quantity, a share, η_t , is allocated to the non-traded sector, and the remaining share, $(1 - \eta_t)$, to the traded sector. Hence, $l_{1t} \equiv \eta_t(2L - l_{3t})$ and $l_{2t} \equiv (1 - \eta_t)(2L - l_{3t})$.

As in the standard Dutch disease model with mobile labor, the wage rates are identical across sectors in equilibrium. Equating (18) with (19), and applying (24), we find that

$$\eta(\xi)^* = \frac{1}{\frac{1-\phi(1+\xi)}{\phi(1+\xi)} \frac{\beta}{\alpha} + 1}. \quad (33)$$

Assuming $\xi < \frac{1-\phi}{\phi}$, it follows that $0 < \eta(\xi)^* < 1$.

In equilibrium, the marginal value product of labor used in household production equals the wage rate. Female labor used in household production, l_{3t} , can then be derived by combination of (17), (18), (26), and (33):

$$l_3^{ML}(\alpha, \gamma, \phi, \mu, \xi)^* = \left[\frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^*}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \right] 2L. \quad (34)$$

To avoid corner solutions, we need furthermore to assume that

$$\eta(\xi)^* < \frac{\phi \alpha}{\mu \gamma}.$$

If $\eta(\xi)^* = \frac{\phi \alpha}{\mu \gamma}$, the woman uses all her labor endowments, L , in the household, and if $\eta(\xi)^* > \frac{\phi \alpha}{\mu \gamma}$ there is no equilibrium, since $l_3^{ML}(\xi)^*$ cannot exceed L .

By (34), we obtain

$$l_1^{ML}(\alpha, \gamma, \phi, \mu, \xi)^* = \eta(\xi)^* \left[\frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \right] 2L, \quad (35)$$

and

$$l_2^{ML}(\alpha, \gamma, \phi, \mu, \xi)^* = [1 - \eta(\xi)^*] \left[\frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \right] 2L. \quad (36)$$

Both female and male labor allocation depends on the natural resource abundance.

4.2 Static Equilibrium

Having characterized the equilibrium labor allocation, equilibrium values of all other variables can now be obtained. Insertion of equilibrium labor allocation in (24) gives p_{1t}^* , in (25) gives p_{3t}^* , and in (23) gives GDP_t^* in the respective economy. Likewise, wage rates can be derived from (18) and (19). We refer the reader to the Appendix A for this exercise.

As shown in the Appendix A, in all economies; *Men in Trade*, *Women in Trade*, and *Mobile Labor*, wage rates, GDP, and the shadow price of the household good grow that the same rate as productivity growth in the traded sector. The price of the non-traded good - the real exchange rate - grows at the ratio of productivity growth in the traded sector to the non-traded sector. In the following, we describe the dynamics for each economy.

4.3 Dynamics

There is zero learning by doing in the household, and we focus on the two differential equations given in (3) and (4). From these equations it is clear that, in general, output in one sector grows faster than output in the other. By (28), (31), and (34) we can rewrite (3) and (4) as

$$g_1^{MiT*} = \left(\frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1} + \delta \right) L, \quad (37)$$

$$g_2^{MiT*} = \left(\frac{\delta}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1} + 1 \right) L, \quad (38)$$

and,

$$g_1^{WiT}(\xi)^* = \left[1 + \frac{\delta}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L, \quad (39)$$

$$g_2^{WiT}(\xi)^* = \left[\delta + \frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L, \quad (40)$$

and,

$$g_1^{ML}(\xi)^* = \frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \{ \eta(\xi)^* + \delta[1 - \eta(\xi)^*] \} 2L, \quad (41)$$

$$g_2^{ML}(\xi)^* = \frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \{ \delta \eta(\xi)^* + [1 - \eta(\xi)^*] \} 2L, \quad (42)$$

for the three economies respectively. Productivity growth in either sector in either economy is constant. Moreover, when the learning by doing spillover across sectors is less than the direct effect; i.e., when $\delta < 1$, in the *MiT* economy

$$g_1^{MiT*} - g_2^{MiT*} = (\delta - 1) \frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha}}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1} L < 0, \quad (43)$$

whereas, in the *WiT* economy,

$$g_1^{WiT}(\xi)^* - g_2^{WiT}(\xi)^* = (1 - \delta) \frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta}}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} L > 0. \quad (44)$$

Independently of how gender and sectors are combined, output in the sector that employs male labor grows faster than output in the sector that employs female labor. Hence, the asymptotic growth rate is given by the male sector. The reason is that as the woman uses a share of her labor endowments in household production, the direct effect of learning by doing generated by female labor is less than the direct effect of learning by doing generated by male labor. Thus, when spillover effects are only a fraction of the direct effects, productivity growth in the female sector is less than productivity growth in the male sector.

When spillover is perfect, in which case $\delta = 1$, from either of (3) and (4), we find that two sectors grow at the same rate. Specifically,

$$g^{MiT*} = \left(\frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1} + 1 \right) L, \quad (45)$$

$$g^{WiT}(\xi)^* = \left[1 + \frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] L. \quad (46)$$

In contrast, in a *ML* economy,

$$g_1^{ML}(\xi)^* - g_2^{ML}(\xi)^* = (1 - \delta) \frac{2\eta(\xi)^* - 1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} 2L > 0 \text{ if } \eta(\xi)^* > \frac{1}{2}. \quad (47)$$

Output in the sector which employs the largest share of the labor force grows faster than the other sector, and the asymptotic growth rate is given by this sector. When $\eta^* = \frac{1}{2}$, the two sectors grow at the same rate. The two sectors also grow at the same rate when spillovers are perfect, in which case, the growth rate is given as

$$g^{ML}(\xi)^* = \frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} 2L. \quad (48)$$

Having solved the model and described the dynamics of the three economies, the next section analyzes the role of the natural resource abundance upon the performance in each economy.

5 Resource Impact

The Dutch disease is named after a sequence of reactions shown by the Dutch economy after discovery of large natural gas reserves in the Netherlands. Classical Dutch disease symptoms include appreciation of the real exchange rate, i.e., an increase in p_{1t}^* , and a decline in the share of the labor force employed in the traded sector whereby the economy's competitiveness with respect to imports is hurt. It is typically assumed that productivity is generated purely in the traded sector; thus, the long-run growth rate is also harmed. An exception to these results is found in Torvik (2001) where the real exchange rate depreciates in response to larger natural resource revenue flows, but the long-run growth rate is unaffected.

In the following, we analyze and discuss for each economy how it adjusts to a permanent change in ξ . We examine how the economy in general and female labor allocation in particular are affected.

5.1 Dutch Disease Symptoms in the MiT Economy

We begin the analysis by given the following results:

PROPOSITION 1. *Let $\xi \geq 0$. In a MiT economy, an increase in resource abundance, i.e., in ξ :*

(i) *has no impact on female labor supply;*

- (ii) leads to appreciation of the real exchange rate;
- (iii) increases the woman's wage rate relative to the man's wage rate;
- (iv) increases the man-made output and the GDP level; and,
- (v) has no impact on productivity growth.

PROOF. See Appendix B.

These results diverge from the traditional Dutch disease result in one respect: employment in the non-traded and traded sector remains unaffected as the resource abundance expands. The intuition is as follows: The higher the resource abundance, the larger the gap between production and consumption of the traded good. To keep budget shares constant, demand for the non-traded good increases, and the real exchange rate appreciates. This is the effect that traditionally shifts employment from the traded sector to the non-traded sector. In our model, however, we have an additional effect. Also demand for the household good increases and the shadow price of the household good appreciates.¹⁷ Indeed, female labor allocation remains unaffected since demand and supply of the non-traded good and of the household good shift equally up. In the new equilibrium, only domestic output prices have changed.

As the wage rate in the non-traded sector depends upon the real exchange rate, despite the constant factor allocation, women's wage rate increases. The male wage rate, on the other hand, is unaffected by the change in the resource abundance since the price of the traded good is exogenous and male labor is immobile. Hence, if male wage rates initially are higher than female, the wage gap between men and women decreases.

Both man-made output and GDP levels increase since, besides a positive effect which arises from the resource itself, also a positive effect on output in the non-traded sector arises from the appreciation of the real exchange rate. Productivity growth remains unaffected as the labor allocation and labor supply determine learning by doing. Hence, in a *MiT* economy, higher resource abundance merely implies

¹⁷To see this, by (50) $\frac{\partial p_{2t}^{MiT}(\xi)^*}{\partial \xi} = H_{2t} L^{\beta-\gamma} \left(\frac{\mu}{\phi} \frac{\gamma+\alpha}{\gamma} \right)^\gamma \frac{\mu}{[1-\phi(1+\xi)]^2} > 0$.

positive level effects.

5.2 Dutch Disease Symptoms in the WiT Economy

Again, we begin by stating the following results:

PROPOSITION 2. *Let $0 \leq \xi < \frac{1-\phi}{\phi}$. In the WiT economy, an increase in resource abundance, i.e., in ξ :*

- (i) decreases female labor supply;*
- (ii) leads to appreciation of the real exchange rate;*
- (iii) increases the man's and woman's wage rate, but the female to male wage ratio decreases;*
- (iv) increases man-made output and the GDP level; and,*
- (v) causes productivity growth to decline.*

PROOF. See Appendix B.

Similar to the *MiT* economy, as resource abundance increases; demand for the household good and for the non-traded good increases. The man cannot supply more labor to the non-traded sector, but, to meet demand for the household good, the woman withdraws from the labor force and allocates more labor for household use. The *WiT* economy therefore exhibits the classical Dutch disease symptom of contraction of the traded sector. In our model, however, the reason is that the female labor force participation declines; not that female labor moves to the non-traded sector.

As the woman withdraws a share of her labor endowments from the labor force, production of the traded good goes down. To keep budget shares constant, demand for the non-traded good also declines. On the other hand, higher resource abundance imposes a larger gap between production and consumption of the traded good, which, in turn, increases the price of the non-traded good. As the latter effect is stronger, the real exchange rate appreciates.

Both men's and women's wage rate increases. The female wage rate increases as the marginal productivity of female labor goes up concurrently with the woman

moving out of the labor force, whereas the male wage rate increases as the real exchange rate appreciates.

A positive level effect on man-made output arises from the appreciation of the real exchange rate, whereas a negative level effect arises from the contraction of the traded sector, and the former effect dominates. In addition, the GDP level benefits also from the resource revenue itself.

There is no ambiguity in the growth effects. When learning by doing spillovers are less than their direct effects ($\delta < 1$), productivity growth in the traded sector is relatively more damaged by increased resource abundance than productivity growth in the non-traded sector. Since productivity growth is already higher in the non-traded sector (the male sector), this means that the productivity gap between the two formal sectors increases further with higher levels of resource inflows; i.e., the productivity ratio, $\frac{H_{2t}}{H_{1t}}$, falls. Hence, the real exchange rate appreciates at a rate faster than prior to the increase in natural resource abundance.

In contrast, when spillovers are perfect ($\delta = 1$), the growth rate is equally affected in the two sectors. In this case, p_{1t}^{WiT*} is constant, and the only resource impact on the real exchange rate is a level effect.

Recall that wage rates, the GDP level, and the shadow price of the household good all grow at the same rate as productivity growth in the traded sector, g_2^{WiT} . Therefore, these variables all grow at slower rates in response to the increase in natural resource abundance.

5.3 Dutch Disease Symptoms in the ML Economy

When labor is mobile, in addition to women's labor supply, we also analyze how the labor force dispersion between the formal sectors is influenced.

PROPOSITION 3. *Let $0 \leq \xi < \frac{1-\phi}{\phi}$ and $\eta(\xi)^* < \frac{\phi}{\mu} \frac{\alpha}{\gamma}$. In the ML economy, an increase in resource abundance, i.e., in ξ :*

(i.a) increases the share of the labor force employed in the non-traded sector, but decreases female labor supply;

- (i.b) increases employment in the non-traded sector;
(ii) has an ambiguous effect on the real exchange rate;
(iii) increases the wage rate;
(iv) has an ambiguous effect on the man-made output and the GDP level; and;
(v) causes productivity growth to decline in the traded sector, but the effect on productivity growth in the non-traded sector is ambiguous.

PROOF. See Appendix B.

Property (i.a) means that there are two opposite effects on employment in the non-traded sector: The labor force declines as the woman uses more labor in the household sector, but a larger share of the remaining labor force is employed in the non-traded sector. As the latter effect dominates, the non-traded sector enlarges. The traded sector, on the other hand, contracts, and contracts even stronger than in traditional Dutch disease models due to the additional effect from the reduced female labor force participation.

Similar to the gender segregated economies, enhanced natural resource abundance increases the gap between production and consumption of the traded good, which in turn pushes the real exchange rate upwards. As women withdraw from the labor force, however, and as the share of the remaining labor force in the traded sector declines, production of the traded good declines as well. This feedback effect draws the real exchange rate downwards. Moreover, the change in $p_{1t}^{ML}(\xi)^*$ depends also on the change in employment in the non-traded sector. As this employment goes up, to keep budget shares constant, $p_{1t}^{ML}(\xi)^*$ adjusts downwards. As a result, despite a contraction of the traded sector, the real exchange rate does not necessarily appreciate. For these reasons, also the man-made output level, as well as the GDP level, may increase or decline.

It is intuitive that the wage rate increases. As fewer labor resources are employed in the traded sector, marginal labor productivity increases. As the wage is identical across sectors in the *ML* economy, both men and women earn the same - higher - wage.

The change in natural resource abundance affects the growth rate through several channels. First, as the woman decreases her labor supply, less learning by doing is generated. Second, the expansion of non-traded sector has a direct positive effect on learning by doing in this sector and on the spillover to the traded sector. Third, however, as the traded sector contracts, there is less learning by doing in the traded sector, and less spillover of learning by doing to the non-traded sector.

When $\delta = 1$, the positive learning by doing effect from the non-traded sector onto growth is smaller than the negative learning by doing effect from the contracting traded sector. In this case,

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} = \frac{\partial g_2^{ML}(\xi)^*}{\partial \xi} = \frac{\eta(\xi)^*}{\partial \xi} \left\{ \frac{-\frac{\mu}{\phi} \frac{\gamma}{\alpha}}{\left[\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1 \right]^2} \right\} 2L < 0.$$

When spillovers are completely missing, i.e., when $\delta = 0$, then

$$\begin{aligned} \frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} &= \frac{\eta(\xi)^*}{\partial \xi} \left[\frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \right]^2 2L > 0, \\ \frac{\partial g_2^{ML}(\xi)^*}{\partial \xi} &= \frac{\eta(\xi)^*}{\partial \xi} \left\{ \frac{-\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1}{\left[\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1 \right]^2} \right\} 2L < 0. \end{aligned}$$

In this case, increased resource abundance has a positive effect on productivity growth in the non-traded sector, as it depends only this sector's employment.

When spillovers are not perfect, we notice furthermore that, like the *WiT* economy, productivity growth in the traded sector is damaged relatively more than productivity growth in the non-traded sector. Hence, if $\eta(\xi)^* > \frac{1}{2}$, i.e., if $g_1^{ML}(\xi)^* > g_2^{ML}(\xi)^*$, the extra resource revenue makes the real exchange rate depreciate at an even higher rate than prior to the change, whereas if $\eta(\xi)^* < \frac{1}{2}$, i.e., if $g_1^{ML}(\xi)^* < g_2^{ML}(\xi)^*$, the extra revenue makes the real exchange rate appreciate at slower rates.

5.4 Discussion

In terms of resource impact, the previous section demonstrates considerable variation in the Dutch disease symptoms among the three template economies. Our

model illustrates, not only how labor market structures influence the resource impact, but also how, in turn, resource abundance influences women's labor force participation.

The *MiT* economy has a high level of gender equality in how the natural resource impacts the economy. High resource abundance does not effect women's labor supply, and, assuming men earn a higher wage than women, men's and women's wages become more equal at higher resource abundance levels. In contrast, resources have an adverse effect on women's labor force participation in both a *WiT* and *ML* economy. Women at work in these two economies, become more isolated the higher the demand for the home good. One may argue that this isolation is likely to restrain these women's abilities to further their own interests, and, consequently, leave the male part of the labor force in power to rule society. This hypothesis is examined empirically in Ross (2006). Women throughout the Middle East predominantly work in traded sectors; thus the Middle East economies resemble the *WiT* economy, or a modified *ML* economy in which men can work in all sectors, but women can only work in trade. Ross finds that women in *oil rich* Middle East nations hold fewer seats in parliament and are less represented in the non-agricultural labor force than women in Middle East nations with *fewer oil* resources, which is precisely what our model predicts.

At the same time, our model may also explain why women in OECD-countries with a large share of GDP in natural resources, such as, e.g., Canada and New Zealand, despite the resources, comprise above 40 percent of total employment (Anker 1998). Women in these countries occupy a large portion of jobs in the non-traded sector, such as in sales and services, as depicted in table 2 above. Exactly this type of economy resembles our *MiT* economy in which female labor force participation rates are unaffected by resource revenues.

In addition, our model can be paralleled to the general literature on female labor force participation rates. Within this literature, a number of cross country studies have found a U-shaped relationship between female labor force participation rates and per capita GDP levels (Goldin 1995; Mammen and Paxson 2000). The down-

ward sloping section of the U-shaped pattern is in conformity with our analysis of a *WiT* economy and *ML* economy, in which, the GDP level effect caused by increased resource abundance is positive. These scenarios predict exactly a negative relationship between female labor force participation and GDP levels. Women withdraw from the labor force because, in response to the higher income levels, the household good is demanded more.

6 Concluding Remarks

By studying labor mobility - and labor immobility - across formal sectors, and endogenous female labor supply, we explain manifold economic adjustment outcomes to increased resource abundance within a Dutch disease model. In particular, our analysis shows that labor market patterns are crucial to the adjustment outcome.

When sectors are *gender segregated*, whether women work in the traded or in the non-traded sector determines how the economy responds to increased resource abundance. In both economies, such a change results in higher demand for the household good as well as the non-traded good. If women work in the traded sector, they supply less labor to the formal sector to meet increased demand for the household good. In contrast, if women work in the non-traded sector, factor allocation and labor supply remains unchanged, since both goods in question are produced by women. Growth arises from learning by doing and depends on the size, and the allocation, of the labor force. Thus, growth is unaffected by increases in the resource inflow when women work in the non-traded sector and adversely affected when women work in the traded sector. Despite the latter adverse growth effect, higher resource abundance is, nevertheless, a blessing in terms of improving the GDP level.

When labor is *mobile between formal sectors*, i.e., when men and women work in the same sectors, as resource abundance increases, women withdraw from the labor force to meet demand for the household good. At the same time, a larger share of the remaining labor force is allocated to the non-traded sector to meet demand for

the non-traded good. Due to this complexity of the labor-reallocation adjustment to changed resource abundance, the GDP level only rises when contraction of the traded sector is not too large; otherwise it declines, just as the productivity growth in the non-traded sector increases only when sectoral spillovers are absent. When sectoral spillovers are perfect, however, productivity growth, which in this case is identical in the two sectors, declines.

Also the resource impact on the real exchange rate and the wage rates depends on the gender-grouping of the labor market. The wage rates generally differ between sectors when labor is immobile. Moreover, when men work in trade, only female wages are boosted by increased resource abundance, whereas, when men work in the non-traded sector, both female and male wages increase. There is merely one wage rate when labor is mobile. This wage rate is higher, the greater the resource abundance.

Our results demonstrate that linking labor market patterns to natural resource abundance may also explain certain structures of society. In particular, when women have employment possibilities in the traded sector, abundant natural resources “tie women to the home.”

Future work may involve policy and welfare analysis. For this purpose, theoretical work that involves intergenerational considerations seems useful. For instance, Matsen and Torvik (2005) analyze a Dutch disease model with mobile labor and exogenously given labor supply and find that some reduction in growth is optimal.

A Appendix

A.1 Static Equilibrium of the MiT Economy

Using $l_1^{MiT}(\alpha, \gamma, \phi, \mu)^*$ and $l_{2t}^* = L$, from (24), the equilibrium price of the non-traded good is

$$p_{1t}^{MiT}(H_{1t}, H_{2t}; \xi)^* = \frac{H_{2t}}{H_{1t}} L^{\beta-\alpha} \left(\frac{\mu \gamma}{\phi \alpha} + 1 \right)^\alpha \frac{\phi(1+\xi)}{1-\phi(1+\xi)}, \quad (49)$$

and, likewise, the equilibrium imputed price of the household good is derived from (25) as

$$p_{3t}^{MiT}(H_{2t}; \xi)^* = H_{2t} L^{\beta-\gamma} \left(\frac{\frac{\mu \gamma}{\phi \alpha} + 1}{\frac{\mu \gamma}{\phi \alpha}} \right)^\gamma \frac{\mu(1+\xi)}{1-\phi(1+\xi)}. \quad (50)$$

Both equilibrium prices are functions of labor allocation and the adjusted budget shares. The higher the labor share in production in a given sector, the lower the equilibrium price of the corresponding output due to decreasing marginal productivity of labor. Moreover, the larger ξ , the larger the adjusted budget share, which implies a higher equilibrium price.

Due to the segmented nature of the labor market, wage rates generally differ between sectors. As $w_{1t}^{MiT} \equiv w_t^f$, and by (18), (28), and (50), the female wage rate in equilibrium is

$$w_t^f(H_{2t}; \xi)^* = H_{2t} L^{\beta-1} \left(\frac{\mu \gamma}{\phi \alpha} + 1 \right) \frac{\phi(1+\xi)}{1-\phi(1+\xi)}. \quad (51)$$

The wage rate in the traded sector is paid to men, so $w_{2t}^{MiT} \equiv w_t^m$, and, in equilibrium, is given as

$$w_t^m(H_{2t})^* = H_{2t} \beta L^{\beta-1} \quad (52)$$

by (20) and (19). We notice that the female wage rate depends directly on the resource abundance, which is a result of the impact the resource abundance has on the price of the non-traded good. The male wage rate, on the other hand, depends on the world market price on the traded good, which is unaffected by the inflow of natural resources.

Man-made output is the sum of output in the two formal sectors,

$$y_t^{MiT}(H_{2t}; \xi)^* = H_{2t} L^\beta \frac{1}{1-\phi(1+\xi)}, \quad (53)$$

and by (23), GDP can be derived as

$$GDP_t^{MiT}(H_{2t}; \xi)^* = H_{2t}L^\beta \frac{1 + \xi}{1 - \phi(1 + \xi)}. \quad (54)$$

A.2 Static Equilibrium of the WiT Economy

Using $l_2^{WiT}(\beta, \gamma, \phi, \mu, \xi)^*$ and $l_{1t}^* = L$, The equilibrium price of the non-traded good can be expressed from (24):

$$p_{1t}^{WiT}(H_{1t}, H_{2t}; \xi)^* = \frac{H_{2t}}{H_{1t}} L^{\beta-\alpha} \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right]^\beta \frac{\phi(1 + \xi)}{1 - \phi(1 + \xi)}, \quad (55)$$

and likewise, the imputed price of the household good in equilibrium is by (25):

$$p_{3t}^{WiT}(H_{2t}; \xi)^* = H_{2t}L^{\beta-\gamma} \frac{\left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right]^\beta}{\left[\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1 \right]^\gamma} \frac{\mu(1 + \xi)}{1 - \phi(1 + \xi)}. \quad (56)$$

The wage rate in the non-traded sector is earned by men. By (18) and (55):

$$w_t^m(H_{2t}; \xi)^* = H_{2t}\alpha L^{\beta-1} \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right]^\beta \frac{\phi(1 + \xi)}{1 - \phi(1 + \xi)}. \quad (57)$$

The wage rate within the traded sector is earned by women, and from (19) and (31):

$$w_t^f(H_{2t}; \xi)^* = H_{2t}\beta L^{\beta-1} \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right]^{\beta-1}. \quad (58)$$

Man-made output, $y_t^{WiT}(H_{2t}; \xi)^*$, is given as

$$y_t^{WiT}(H_{2t}; \xi)^* = H_{2t}L^\beta \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right]^\beta \frac{1}{1 - \phi(1 + \xi)}, \quad (59)$$

and, by (23),

$$GDP_t^{WiT}(H_{2t}; \xi)^* = H_{2t}L^\beta \left[\frac{1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right]^\beta \frac{1 + \xi}{1 - \phi(1 + \xi)}. \quad (60)$$

A.3 Static Equilibrium of the ML Economy

Using $l_3^{ML}(\alpha, \gamma, \phi, \mu, \xi)^*$, the equilibrium price of the non-traded good is derived from (24):

$$p_{1t}^{ML}(H_{1t}, H_{2t}; \xi)^* = \frac{H_{2t}}{H_{1t}} [2L - l_3(\xi)^*]^{\beta-\alpha} \frac{[1 - \eta(\xi)^*]^\beta}{[\eta(\xi)^*]^\alpha} \frac{\phi(1 + \xi)}{1 - \phi(1 + \xi)}, \quad (61)$$

and the equilibrium imputed price of the household good from (25):

$$p_{3t}^{ML}(H_{2t}; \xi)^* = H_{2t} [2L - l_3(\xi)^*]^\beta \frac{[1 - \eta(\xi)^*]^\beta}{[l_3(\xi)^*]^\gamma} \frac{\mu(1 + \xi)}{1 - \phi(1 + \xi)}. \quad (62)$$

By (19), the wage rate is given as

$$w_t^{ML}(H_{2t}; \xi)^* = H_{2t}^\beta \{ [1 - \eta(\xi)^*] [2L - l_3(\xi)^*] \}^{\beta-1}. \quad (63)$$

Man-made output is given as

$$y_t^{ML}(H_{2t}; \xi)^* = \frac{1}{1 - \phi(1 + \xi)} H_{2t} [1 - \eta(\xi)^*]^\beta [2L - l_3(\xi)^*]^\beta. \quad (64)$$

and the GDP level, by (23), is

$$GDP_t^{ML}(H_{2t}; \xi)^* = \frac{1 + \xi}{1 - \phi(1 + \xi)} H_{2t} [1 - \eta(\xi)^*]^\beta [2L - l_3(\xi)^*]^\beta. \quad (65)$$

B Appendix

B.1 Proof of Proposition 1

We prove each property (i)-(v) in turn by differentiation.

B.1.1 Proof of (i)

By (28),

$$\frac{\partial l_{1t}^{MiT*}}{\partial \xi} = 0. \quad \square$$

B.1.2 Proof of (ii)

From (49)

$$\frac{\partial p_{1t}^{MiT}(\xi)^*}{\partial \xi} = \frac{H_{2t}}{H_{1t}} L^{\beta-\alpha} \left(\frac{\mu \gamma}{\phi \alpha} + 1 \right)^\alpha \frac{\phi}{[1 - \phi(1 + \xi)]^2} > 0. \quad \square$$

B.1.3 Proof of (iii)

By (51)

$$\frac{\partial w_t^f(H_{2t}; \xi)^*}{\partial \xi} = H_{2t} L^{\beta-1} \left(\frac{\mu \gamma}{\phi \alpha} + 1 \right) \frac{\phi}{[1 - \phi(1 + \xi)]^2} > 0,$$

and by and (52)

$$\frac{\partial w_t^m(H_{2t})^*}{\partial \xi} = 0.$$

Let the female to male wage ratio be given by $\rho_t(\xi)^* \equiv \frac{w_t^f(\xi)^*}{w_t^m(\xi)^*}$. Then, by (51) and (52),

$$\rho(\xi)^* = \frac{\alpha + \frac{\mu}{\phi} \gamma}{\beta} \frac{\phi(1 + \xi)}{1 - \phi(1 + \xi)},$$

and

$$\frac{\partial \rho(\xi)^*}{\partial \xi} = \frac{\alpha + \frac{\mu}{\phi} \gamma}{\beta} \frac{\phi}{[1 - \phi(1 + \xi)]^2} > 0. \quad \square$$

B.1.4 Proof of (iv)

By (53),

$$\frac{\partial y_t^{MiT}(\xi)^*}{\partial \xi} = H_{2t} L^\beta \frac{\phi}{[1 - \phi(1 + \xi)]^2} > 0,$$

and by (54),

$$\frac{\partial GDP_t^{MiT}(\xi)^*}{\partial \xi} = H_{2t} L^\beta \left\{ \frac{1}{[1 - \phi(1 + \xi)]^2} \right\} > 0. \quad \square$$

B.1.5 Proof of (v)

From (37),

$$\frac{\partial g_1^{MiT*}}{\partial \xi} = 0,$$

and from and (38),

$$\frac{\partial g_2^{MiT*}}{\partial \xi} = 0.$$

This proves property (v) and completes the proof of proposition 1. \square

B.2 Proof of Proposition 2

We prove each property (i)-(v) in turn by differentiation.

B.2.1 Proof of (i)

By (31), $\frac{\partial l_2^{WiT}(\xi)^*}{\partial \xi} = l_2^{WiT}(\xi)^* \left[-\frac{\frac{\mu\gamma}{1-\phi(1+\xi)}}{\mu\gamma(1+\xi)+\beta[1-\phi(1+\xi)]} \right] < 0. \quad \square$

B.2.2 Proof of (ii)

From (55),

$$\frac{\partial p_{1t}^{WiT}(\xi)^*}{\partial \xi} = \frac{p_{1t}^{WiT}(\xi)^*}{1 - \phi(1 + \xi)} \left[\frac{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} (1 - \beta) + 1}{\frac{\mu(1+\xi)}{1-\phi(1+\xi)} \frac{\gamma}{\beta} + 1} \right] > 0. \quad \square$$

B.2.3 Proof of (iii)

By (57),

$$\frac{\partial w_t^m(H_{2t}; \xi)^*}{\partial \xi} = \alpha H_{1t} L^{1-\alpha} \frac{\partial p_{1t}^{WiT}(\xi)^*}{\partial \xi} > 0.$$

and by and (58)

$$\frac{\partial w_t^f(H_{2t}; \xi)^*}{\partial \xi} = H_{2t}(\beta - 1) [l_2^{WiT}(\xi)^*]^{\beta-2} \frac{\partial l_2^{WiT}(\xi)^*}{\partial \xi} > 0.$$

Let the female to male wage rate ratio be given by $\rho_t(\xi)^* \equiv \frac{w_t^f(\xi)^*}{w_t^m(\xi)^*}$. Then, by (57) and (58),

$$\rho(\xi)^* = \frac{\mu\gamma + \beta \left[\frac{1}{1+\xi} - \phi \right]}{\phi\alpha}.$$

and,

$$\frac{\partial \rho(\xi)^*}{\partial \xi} = \frac{-\beta}{\phi\alpha [1+\xi]^2} < 0. \quad \square$$

B.2.4 Proof of (iv)

By (59),

$$\frac{\partial y_t^{WiT}(\xi)^*}{\partial \xi} = \frac{H_{2t} [l_2^{WiT}(\xi)^*]^\beta}{[1 - \phi(1+\xi)]^2} \left[\phi - \frac{\mu\gamma\beta}{\mu(1+\xi)\gamma + \beta [1 - \phi(1+\xi)]} \right] > 0$$

and by (60),

$$\frac{\partial GDP_t^{WiT}(\xi)^*}{\partial \xi} = \frac{H_{2t} [l_2^{WiT}(\xi)^*]^\beta}{[1 - \phi(1+\xi)]^2} (1+\xi) \left[\frac{1}{1+\xi} - \frac{\mu\gamma\beta}{\mu(1+\xi)\gamma + \beta [1 - \phi(1+\xi)]} \right] > 0. \quad \square$$

B.2.5 Proof of (v)

From (39),

$$\frac{\partial g_1^{WiT}(\xi)^*}{\partial \xi} = \delta \frac{\partial l_2^{WiT}(\xi)^*}{\partial \xi} < 0$$

and, from (40),

$$\frac{\partial g_2^{WiT}(\xi)^*}{\partial \xi} = \frac{\partial l_2^{WiT}(\xi)^*}{\partial \xi} < 0.$$

This proves property (v) and completes the proof of proposition 2. \square

B.3 Proof of Proposition 3

We prove each property (i.a)-(v) in turn by differentiation.

B.3.1 Proof of (i.a)

By (33),

$$\frac{\eta(\xi)^*}{\partial \xi} = [\eta(\xi)^*]^2 \frac{\beta}{\alpha \phi(1+\xi)^2} > 0,$$

and, by (34),

$$\frac{l_3^{ML}(\xi)^*}{\partial \xi} = \frac{\eta(\xi)^*}{\partial \xi} \frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha}}{\left[\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1 \right]^2} 2L > 0. \quad \square$$

B.3.2 Proof of (i.b)

As $l_1^{ML}(\xi, \cdot)^* = \eta(\xi)^*[2L - l_3^{ML}(\xi)^*]$, it follows that

$$\frac{l_1^{ML}(\xi)^*}{\partial \xi} = \frac{\eta(\xi)^*}{\partial \xi} \left[\frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \right]^2 2L > 0. \quad \square$$

B.3.3 Proof of (ii)

From (61),

$$\frac{\partial p_{1t}^{ML}(\xi)^*}{\partial \xi} = p_{1t}^{ML}(\xi)^* \left\{ \frac{1}{[1 - \phi(1 + \xi)](1 + \xi)} - \frac{\frac{\eta(\xi)^*}{\partial \xi}}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \left[\frac{\beta \left[\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1 \right]}{1 - \eta(\xi)^*} + \frac{\alpha}{\eta(\xi)^*} \right] \right\}.$$

Thus,

$$\frac{\partial p_{1t}^{ML}(\xi)^*}{\partial \xi} > 0 \text{ if } \frac{1}{[1 - \phi(1 + \xi)](1 + \xi)} > \frac{\frac{\eta(\xi)^*}{\partial \xi}}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \left[\frac{\beta \left[\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1 \right]}{1 - \eta(\xi)^*} + \frac{\alpha}{\eta(\xi)^*} \right],$$

otherwise

$$\frac{\partial p_{1t}^{ML}(\xi)^*}{\partial \xi} < 0. \quad \square$$

B.3.4 Proof of (iii)

By (63),

$$\frac{\partial w_t^{ML}(\xi)^*}{\partial \xi} = \beta H_{2t}(\beta - 1)[l_2^{ML}(\xi)^*]^{\beta-2} \left[\frac{l_2^{ML}(\xi)^*}{\partial \xi} \right] > 0.$$

Since

$$\frac{l_2^{ML}(\xi)^*}{\partial \xi} = -\frac{\eta(\xi)^*}{\partial \xi} \frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1}{\left[\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1 \right]^2} 2L < 0. \quad \square$$

B.3.5 Proof of (iv)

By (64)

$$\frac{\partial y_t^{ML}(H_{2t}; \xi)^*}{\partial \xi} = y_t^{ML}(H_{2t}; \xi)^* \left\{ \frac{\phi}{1 - \phi(1 + \xi)} + \beta \frac{l_2^{ML}(\xi)^*}{l_2^{ML}(\xi)^*} \right\},$$

where

$$\frac{l_2^{ML}(\xi)^*}{l_2^{ML}(\xi)^*} = - \frac{\frac{\eta(\xi)^*}{\partial \xi} \frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha} + 1}{[1 - \eta(\xi)^*] \frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1}}$$

Hence,

$$\frac{\partial y_t^{ML}(H_{2t}; \xi)^*}{\partial \xi} > 0 \text{ if } \frac{\phi}{1 - \phi(1 + \xi)} > \beta \frac{l_2^{ML}(\xi)^*}{l_2^{ML}(\xi)^*},$$

otherwise,

$$\frac{\partial y_t^{ML}(H_{2t}; \xi)^*}{\partial \xi} < 0.$$

From, (65)

$$\frac{\partial GDP_t^{ML}(\xi)^*}{\partial \xi} = y_t^{ML}(\xi)^* + (1 + \xi) \frac{\partial y_t^{ML}(H_{2t}; \xi)^*}{\partial \xi}.$$

Hence,

$$\frac{\partial GDP_t^{ML}(\xi)^*}{\partial \xi} > 0 \text{ if } \frac{1}{1 + \xi} + \frac{\phi}{1 - \phi(1 + \xi)} > \beta \frac{l_2^{ML}(\xi)^*}{l_2^{ML}(\xi)^*},$$

otherwise,

$$\frac{\partial GDP_t^{ML}(\xi)^*}{\partial \xi} < 0. \quad \square$$

B.3.6 Proof of (v)

By (41),

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} = \frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \frac{\eta(\xi)^*}{\partial \xi} \left\{ - \frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha} [\eta(\xi)^* + \delta(1 - \eta(\xi)^*)]}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} + 1 - \delta \right\} 2L.$$

Thus,

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} \geq 0 \text{ if } 1 \geq \delta + \frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha} [\eta(\xi)^* + \delta(1 - \eta(\xi)^*)]}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1}$$

otherwise,

$$\frac{\partial g_1^{ML}(\xi)^*}{\partial \xi} < 0.$$

By (42),

$$\frac{\partial g_2^{ML}(\xi)^*}{\partial \xi} = \frac{1}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} \frac{\eta(\xi)^*}{\partial \xi} \left\{ -\frac{\frac{\mu}{\phi} \frac{\gamma}{\alpha}}{\frac{\mu}{\phi} \frac{\gamma}{\alpha} \eta(\xi)^* + 1} [1 + \eta(\xi)^* (\delta - 1)] + \delta - 1 \right\} 2L < 0.$$

This proves property (v) and completes the proof of proposition 3. \square

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